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Changes in behavioural synchrony during dog-assisted therapy for children with autism spectrum disorder and children with Down syndrome

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Abstract

Background: Dog-assisted therapy (DAT) is hypothesized to help children with autism spectrum disorder (ASD) and Down syndrome (DS).

Methods: The present authors compared synchronous movement patterns of these children (n = 10) and their therapy dogs during the first and last session of a DAT programme, and their post-therapy changes in emotional and behavioural problems.

Results: The present authors found a significant increase in synchrony between child and therapy dog over time. Exploratory analyses suggest more synchrony between children with ASD and their therapy dogs, compared to the children with DS.

Conclusions: This study is the first to test the synchrony hypothesis, shedding light upon a mechanism that may underlie the effect of DAT and how this may be different for children with ASD and DS.

KEYWORDS

autism spectrum disorder, behavioural synchrony, cross-recurrence quantification analysis, Dog-assisted therapy, Down syndrome

1 | INTRODUCTION

Children with autism spectrum disorder (ASD) show delays and a different developmental course with regard to their cognitive and social–emotional development (e.g. La Malfa, Lassi, Bertelli, Salvini, & Placidi, 2004; McPartland & Volkmar, 2012). Similar delays have been reported for children with Down syndrome (DS) (Kortenhorst, Hazekamp, Rammeloo, Schoof, & Ottenkamp, 2005; Gamerenn-Oosterom et al., 2011; Weijerman & de Winter, 2010). Both children with ASD and DS commonly have attention problems, social problems, language deficits and trouble to engage in social interactions (Eisenhower, Baker, & Blacher, 2005; Weijerman & de Winter, 2010). Although both conditions provide a challenge for caregivers and professionals, the social interaction skills of children with ASD seem more impaired than those of children with DS, especially when it comes to responding to prosocial initiations (Knott, Lewis, & Williams, 1995), joint attention, emotional responsiveness, cooperation and social engagement (Sigman, Ruskin, Arbeile, et al., 1999; Sigman, Ruskin, Arbelle, et al., 1999).

An important part of social interaction is behavioural synchrony, which is generally conceptualized as "an observable pattern of dyadic interaction that is mutually regulated, reciprocal, and harmonious" (Harrist & Waugh, 2002, p. 557). Synchrony in dyadic interactions facilitates children's social, emotional and cognitive growth (Beebe, Sorter, Rustin, & Knoblauch, 2003; Feldman, 2007; Forster & Iacono, 2014; Harrist & Waugh, 2002; Jaffe et al., 2001; Stern, 2010). While most studies on synchrony focus on caregiver–infant interactions (Feldman, 2007; Harrist & Waugh, 2002), the essence of synchrony is a rhythmic pattern of mutual adaptation shared by (at least) two individuals interacting with each other (Fogel, Dedo, & McEwen, 1992). Synchrony is by definition a social phenomenon (Babad, Bernieri, & Rosenthal, 1991) and a construct of temporal

coordination. This means that synchrony is expressed as a match between the interaction partners' behaviours in time (Feldman, 2007), for example communicative and emotional verbal and non-verbal behaviours such as gestures, movements, postures, vocalizations and gazes between mother and child (Feldman, 2007; Leclère et al., 2014). This results in rhythmic patterns that can be simultaneous and identical, or alternating and mirrored (Fogel et al., 1992).

Previous studies suggest that dyads often fail to achieve synchrony when the child is diagnosed with ASD or DS. Again, this may be more pronounced for children with ASD (Baranek, 1999; Osterling, Dawson, & Munson, 2002; Sigman, Ruskin, Arbeile, et al., 1999; Sigman, Ruskin, Arbelle, et al., 1999). Even before an official diagnosis is made, parents of children with ASD report impaired social interaction, as well as a failure to show joint attention and communicative pointing (Osterling & Dawson, 1994; Trevarthen & Daniel, 2005), and difficulties to respond to their own name and to imitate others (Landa, 2007). This makes it hard to achieve the mutual regulation and temporal coordination that characterizes behavioural synchrony. In contrast, although the affective expressions of young children with DS are less lively and they engage more in stereotypical play, researchers have reported more joint attention behaviours and a preference for social stimuli (Baranek, 1999; Kasari & Freeman, 2001). Compared to typically developing children, however, children with DS show more problems when interacting with others (Naess, Nygaard, Ostad, Dolva, & Halaas Lyster, 2017). These problems seem to be related to their language deficits (Naess et al., 2017; Sigman, Ruskin, Arbeile, et al., 1999; Sigman, Ruskin, Arbelle, et al., 1999). Moreover, given that children with DS are more prone to sensory problems such as hearing loss and motor difficulties, the timing and flow of their social interactions may be affected, compromising synchrony (Roberts, Price, & Malkin, 2007; Rondal, 2009).

Dog-assisted therapy (DAT) may help children with ASD and DS to build synchronous interaction patterns (Finck, 1993; Myers, 2007; Verheggen, Enders-Slegers, & Eshuis, 2017). This therapy consists of structured one-on-one or small group sessions, offered by trained professionals who use certified therapy dogs. The treatment requires the active involvement of the participant and has specific therapeutic goals depending on the participant's needs (Perkins, Bartlett, Travers, & Rand, 2008). Only a few effect studies on DAT have been conducted involving children with ASD and DS. Their findings indicate an increase in social behaviour of children with ASD, such as initiating contact with the therapist and being more focused, as well as a decrease in autistic symptoms, such as hand-flapping, repetitive behaviour and talking about unrelated subjects (Martin & Farnum, 2002; Nimer & Lundahl, 2007; Redefer & Goodman, 1989). Similarly, children with DS had a more sustained focus, performed more cooperative interactions and showed more positive and less negative social behaviour after DAT (Esteves & Stokes, 2008; Limond, Bradshaw, & Cormack, 1997).

Whether children with DS and ASD respond differently to dogs compared to typically developing children is still an aspect to be investigated. O'Haire (O'Haire, 2013) showed that children with ASD engaged in more social approach behaviours towards typically developing peers in the presence of animals. In a more recent paper, O'Haire (O'Haire, Mckenzie, Beck, & Slaughter, 2015) described how children with ASD showed lower physical arousal in the presence of animals. Together, these studies might indicate that animals lower the stress in social situations that children with ASD typically experience.

Some studies mention the effects of having a dog at home (pet ownership). (Silva, Correia, Lima, Magalhães, & de Sousa, 2011), for instance, relate dog ownership to more frequent and longer durations of positive behaviours, such as smiling and physical contacting of children with ASD. This is in line with Carlisle (2015), who reported increased social skills of children with ASD and bonding to their dogs. In addition, positive effects of dog ownership on family functioning and child anxiety and stress are reported by various researchers (Hall, Wright, Hames, & Mills, 2016; Viau et al., 2010; Wright et al., 2015). Lastly, two literature reviews (Berry, Borgi, Francia, Alleva, & Cirulli, 2013; O'Haire, 2017) concluded that animal-assisted interventions increase the social interaction skills of children with ASD. O'Haire's (2017) review included 28 studies over a period from 2012 to 2015 and did find that the most common outcome was increased social interaction among children with ASD. Although these studies are encouraging, there is a need for more research to strengthen the clinical use of DAT interventions (Cirulli, Borgi, Berry, Francia, & Alleva, 2011; O'Haire, 2013), specifically by searching for its underlying mechanism (Berry, Borgi, Francia, Alleva, & Cirulli, 2013; Melson, 1988; Melson & Fogel, 1989).

Several authors state that movement synchrony is a fundamental condition in human–pet interactions (Beck & Katcher, 1996; Fogel et al., 1992; Melson & Fogel, 1989; Verheggen et al., 2017), and the connection people have with animals can be of similar quality to the bond they have with other people (Martin & Farnum, 2002; Sable, 2013; Sanders, 2003). Researchers have therefore hypothesized that therapy dogs serve as "transition objects." The clear-cut way in which dogs communicate enables children with ASD and DS to establish synchronous movement patterns they can later extend to human interactions (Martin & Farnum, 2002; Verheggen et al., 2017; Winnicott, 1986). This synchrony hypothesis has, however, never been tested, making the mechanism of the therapeutic effect of DAT unclear. Previous research does show, however, that human–dog couples are able to synchronize. In a recent study focused on dogs' capacity to synchronize with their owners, Duranton, Bedossa, and Gaunet (2017) investigated in a familiar outdoor space how dogs synchronized their movements with their owners and found that dogs generally stayed close to their owners, and moved and gazed in the same direction. In addition, Pirrone, Ripamonti, Garoni, Stradiotti, and Albertini,(2017) examined synchronous behaviour in four dog–handler dyads during animal-assisted activities. All dyads showed synchronous behaviours, such as gaze synchrony and touch synchrony, particularly with regard to joint attention. While this shows that human–non-human synchronization is possible, research on the mutual attunement between children and (therapy) dogs is still lacking and may provide more information about the underlying mechanism of DAT.

The current study investigates synchrony between children with ASD or DS and therapy dogs, by comparing their rhythmic patterns of synchronous movement during the first and last therapy session of a six-week DAT programme. Our first aim is to respond to the call for more research on DAT interventions (Cirulli et al., 2011; O'Haire, 2013), specifically by investigating the hypothesized mechanism (i.e. synchronous behavioural patterns) that contributes to the effect of this therapy. The present authors expect increased synchrony between child and therapy dog over time. Our second aim is to explore differences between children with ASD and DS in terms of synchrony during the therapy sessions. Here, the present authors expect lower synchrony for children with ASD, since their social problems seem qualitatively different from those of children with DS (DiGuiseppi et al., 2010). Third, this study explores post-therapy changes in children's social problems. The present authors expect a post-therapy decrease in children's emotional and behavioural problems as reported by their parents (cf. Verheggen et al., 2017).

Synchrony is a typical non-linear process (Marwan, Thiel, & Nowaczyk, 2002). Patterns of matching behaviour do not always occur at the *exact* same moment (Stivers et al., 2009), but can be slightly delayed. Research has shown that children with ASD and DS in particular show a delay in postural reaction and have slower reaction times (Inui, Yamanishi, & Tada, 1995; Wallen & Walker, 2010; Welsh & Elliott, 2001). Hence, a non-linear approach is essential to capture the rhythmic patterns of mutual adaptation in interactions involving a child with ASD or DS. The current study therefore uses cross-recurrence quantification analysis (CRQA), a non-linear time-series technique analysing the shared dynamics of two coupled systems (e.g. child and dog) (Cox & van Dijk, 2013; Davis, Pinto, & Kiefer, 2017; de Graag, Cox, Hasselman, Jansen, & Weerth, 2012; Marwan, Carmenromano, Thiel, & Kurths, 2007; Shockley, Butwill, Zbilut, & Webber, 2002; Zbilut, Giuliani, & Webber, 1998).

2 | METHODS

2.1 | Participants

Five children with ASD and five children with DS participated in this study; see Table 1 for participant characteristics. All children with ASD were diagnosed by a child psychiatrist. Three children were diagnosed with an autistic disorder and an intellectual disability, one child was diagnosed with pervasive developmental disorder-not otherwise specified (PDD-NOS) and an intellectual disability, and one child was diagnosed with multiple complex developmental disorder (MCDD). All children with DS were diagnosed by a paediatrician and had no psychiatric comorbidity.

Participants were recruited through an organization for therapy dogs and a foundation that organizes animal-assisted interventions. Parents signed an informed consent, were informed about the study's procedure and were notified that they could withdraw their child from the research at any moment. The Medical Ethics Review Committee of the University of Amsterdam approved the study.

TABLE 1 Details of the 10 participating children

	DS	ASD
Males/Females	4 males/1 female	4 males/1 female
Mean age in years (range)	14 (12–18)	12 (11–13)
Regular primary education	1 male	–
Special education	3 males/1 female	4 males/1 female
Mean total problem score (*SD*)	35.6 (25.12)	78.2 (20.36)
Mean internalizing probl. (*SD*)	10 (7.18)	14.6 (10.76)
Mean externalizing probl. (*SD*)	6.6 (7.86)	23.8 (9.58)

Note: Raw Child Behavior Checklist (CBCL) scores (mean total problem score, mean internalizing problem score and mean externalizing problem score) were obtained at the start of the study and averaged for each group (children with DS and children with ASD). The score for internalizing problems is based on the sum of the Anxious/depressed, Withdrawn/depressed and Somatic complaints scales of the CBCL; externalizing problems combine the Rule-breaking and Aggressive behaviour scales. From the educational background, the present authors can infer that children in this study had an IQ between 40 and 60, based on the eligibility for special education in the Netherlands.

Children who showed aggressive behaviour against animals and children who had a fear of dogs, had dog allergies or severe visual or hearing problems were excluded from participation.

2.2 | Procedure

The therapy consisted of six weekly sessions of 30 min. Each child worked with the same therapist, dog and handler during all six sessions. The handler was responsible for the dog and supervised the behaviour and possible stress signals of the dog. Handlers were instructed not to interfere in the interaction between child and dog, unless the situation called for immediate action (e.g. when the dog showed stress signals). Two therapy dogs (1 Labrador male breed and 1 Labradoodle male breed) were selected because of their mild-mannered behaviour. The therapy was given by two therapists who were trained to work with therapy dogs. Activities during the sessions were selected from the CTAC method (Domènec & Ristol, 2012) and adapted to the setting of our study. The present authors selected psychomotor and socialization activities in particular, for example having the dog follow the child's movements and letting the child exercise his/her balance and be aware of posture and expression, to align with our outcome measures (movement data and CBCL scores, see below).

The therapist explained what was expected of the child and what gestures and encouraging words were needed to work with the dog. During the first phase of each session, the child and the dog, under supervision of the therapist, performed a number of small exercises or repetitions to get used to the tasks. During the second phase of each session, the child was encouraged to build an obstacle course

TABLE 2 Coding categories and description

Category	Behavioural description
Moving towards each other	Child takes (a) clear step(s) in the direction of the dog, or vice versa, or they follow each other through the therapy room, without moving towards another specific target, such as an object. Note that child and dog do not have to reach the other.
Moving to handler or therapist	Child or dog takes (a) clear step(s) in the direction of either the therapist or the handler. Note that this target does not have to be reached.
Moving to object	Child or dog takes (a) clear step(s) in the direction of an object in the room that is used during the therapy sessions, such as a mat, cube or small bench. Note that this target does not have to be reached.
Moving ahead	Child or dog takes (a) clear step(s) within the therapy room, with no apparent target, such as an object, person or each other. This category is also given when the therapist explicitly instructs child or dog to take a certain position within the therapy room.
Stop of movement	Child or dog no longer takes steps in a certain direction. Always use this code to indicate that a certain movement has stopped, even when another movement immediately follows.

Note: All categories were coded separately for the child and the dog and in real time (i.e. continuously throughout the filmed therapy session).

and to lead the dog through a series of obstacles and ask the dog to perform certain commands, such as sitting on a mat, walking on a bench or jumping over a low bar. To complete this obstacle course successfully, the child had to take the lead and give clear instructions to the dog with regard to their moving direction and the tasks the dog needed to perform. Every session, an additional obstacle was added to the course, and children were encouraged to suggest obstacles or tasks for the dog themselves.

All sessions were recorded on video, using a HD camcorder, Panasonic type HC-V750, with an external microphone. Video files were imported to the program MediaCoder (Bos & Steenbeek, 2006) to code the child's and dog's moving directions.

2.3 | Measurements

2.3.1 | Coding of behaviour

A codebook was written to standardize the coding of movement direction of the participant and the dog (Table 2). Four raters completed a training consisting of an explanation of the coding categories and the coding program MediaCoder (Bos & Steenbeek, 2006). This program allows real-time coding of video files and automatically provides a timestamp for each given code. During the training, raters coded one therapy session and compared their codes with those of an expert rater, who constructed the codebook and training. Each rater focused on movement direction and either on the dog or on the participant. Inter-rater reliability was considered sufficient when at least 80% of the codes of the rater and expert rater were similar with regard to both the timing and the chosen category. That is, similar codes given within 2 s of each other were considered as agreement, whereas dissimilar codes or similar codes given more than two seconds apart were considered as disagreement. If the 80% agreement was not reached, raters received an additional explanation of the coding rules and coded a second therapy session, after which the percentage of agreement was determined again. All raters reached sufficient inter-rater reliability (>80%) after coding two sessions and proceeded with coding of the 20 videos.

Video files of the first and last session of the therapy were then coded for all ten participants. Each change in movement direction of the child and dog was coded by means of continuous real-time coding throughout each 30-min therapy session. Codes were given at the onset of movement, that is, right when the child or therapy dog started to lift a leg. The following categories were used: moving towards each other (participant to the dog and vice versa), moving to the therapist, moving to a specific object, moving ahead (e.g. to a specific point within the room) and stop of movement/no movement.

2.3.2 | Child Behavior Checklist

In addition to the analysis of the video's, parents of the ten children completed the Child Behavior Checklist (CBCL; Achenbach, Dumenci, & Rescorla, 2002) before the first and after the last therapy session. The CBCL is widely used and consists of 120 items that assess the child's emotional and behavioural problems. The sum of all these items is known as the total problem score. Answers to questions about similar topics can be combined to form the "broadband" scales of internalizing problems (Anxious/depressed symptoms, Withdrawn/depressed symptoms, Somatic complaints) and externalizing problems (Rule-breaking behaviour, Aggressive behaviour).

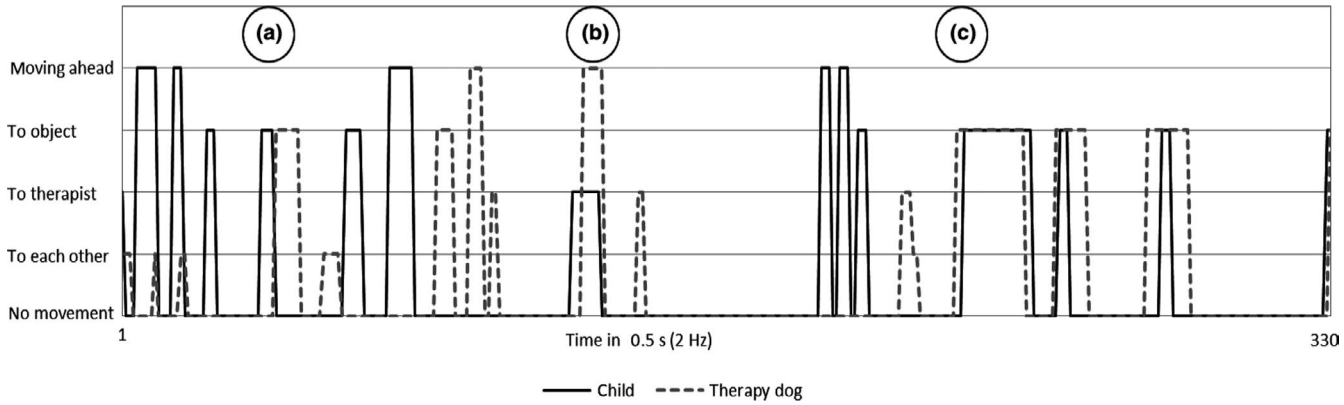

FIGURE 1 Excerpt of time series of child (*M*) and dog during the final therapy session. Three points have been marked to illustrate the meaning of the time series. At point A, the child moves to an object, and the therapy dog follows just when the child stops his movement. At point B, child and therapy dog move in a different direction, when the dog moves to a specific point in the room while the child moves to the therapist. At point C, a series of three movement sequences towards an object start. In all three cases, the therapy dog starts to move first

There is evidence that the CBCL is sufficiently sensitive to detect emotional and behavioural problems of children with intellectual disabilities (Dekker, Koot, Ende, & Verhulst, 2002; Einfeld & Tonge, 1995; Pueschel, Louis, & McKnight, 1991).

2.4 | Data analysis

The present authors transformed the codes and accompanying times to time series with a sampling rate of 2 Hz. On average, these time series were 2,725 data points long (range 1,747–3,609). Figure 1 depicts an excerpt of a time series, as an example. The time series of the participants and dog's movement directions were then subjected to cross-recurrence quantification analysis (CRQA). CRQA analyses the shared dynamics of two coupled systems, based on repeatedly occurring "behavioural matches" between the two time series. These matches are generally called "recurrences." In this case, a behavioural match was defined as both participant and dog moving in the same direction. CRQA detects matches across all possible timescales ranging from half a second to the duration of the entire interaction, by repeatedly shifting the two time series with respect to each other and comparing the behavioural states at every shift (for a more elaborate explanation, see Cox, Steen, Guevara, Jonge-Hoekstra, & Dijk, 2016).

In this study, the present authors analysed the diagonal cross-recurrence profile (DCRP; (Abney, Paxton, Dale, & Kello, 2015; Abney, Warlaumont, Oller, Wallot, & Kello, 2017; Davis et al., 2017; De Jonge-Hoekstra, Steen, Geert, & Cox, 2016; Griffioen, van der Steen, Cox, Verheggen, & Enders-Slegers, 2019; Nomikou, Leonardi, Rohlfing, & Rączaszek-Leonardi, 2016; Reuzel et al., 2013; Richardson & Dale, 2005). That is, the present authors zoomed in on a 30-s window around the main diagonal (also called line of synchrony, LOS) in the recurrence plot. Several measures that can be derived from the DCRP inform about similarities between the two time series. The proportion of synchrony represents the proportion of recurrences on the LOS. This is a rather simple measure of synchrony, as behavioural matches on this line reflect instances in which both participant and dog move in a similar direction at the *exact* same time (i.e. with a lag of zero seconds). The recurrence rate is the proportion of recurrence across the whole DCRP, which gives a more detailed view of the synchrony between participant and dog. In this case, it represents the proportion

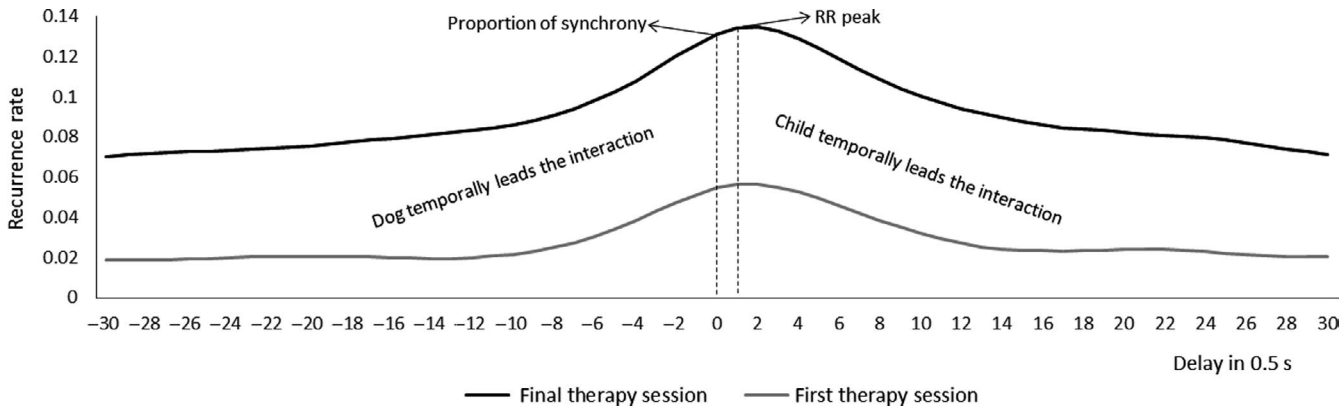

FIGURE 2 Average diagonal cross-recurrence profile (DCRP) plot of this study (n = 10). The x-axis displays the delay in 0.5 s and the y-axis the recurrence rate (the proportion of behavioural matches of participant and dog). The proportion of synchrony represents the proportion of recurrence at the exact same time, while the measure RR_{peak} represents the highest proportion of recurrence within this plot

of behavioural matches of participant and dog in an interval of 15 s on each side of the line of synchrony (30 s in total). RR_{peak} represents the highest proportion of recurrence in this interval. Lastly, Q_{los} depicts the amount of recurrent points in the DCRP on the left side of the LOS divided by the amount of recurrent points in the DCRP on the right side of the LOS. A Q_{los} higher than 1 means that the dog more often temporally leads the interaction, whereas a Q_{los} smaller than 1 means that the child more often temporally leads. Together, these DCRP measures inform about the synchrony between child and the therapy dog in an interval of 30 s around the LOS (see Figure 2).

The present authors then performed a Monte Carlo permutation test to assess whether children's observed recurrence rates of the first and last therapy session exceeded chance level and thus significantly differed from randomly generated recurrence rates (i.e. if a true temporal pattern could be observed). For each child, RR_{peak} was calculated 1,000 times using a random distribution of the original data, that is, without any temporal structure. RR_{peak} was considered significantly different from chance if the probability that the empirical value occurred in these random samples was small.

To examine whether synchrony between child (n = 10) and therapy dog increased over time, the present authors used a repeated measures ANOVA[1] to compare the DCRP measures proportion of synchrony, recurrence rate, RR_{peak} and Q_{los} of the first and last therapy session. The present authors calculated confidence intervals and the generalized eta squared (ηG^2) as a measure of effect size (Lakens, 2013; Olejnik & Algina, 2003). A value of ηG^2 of around 0.02 is considered small, 0.13 medium and 0.26 large (Bakeman, 2005).

The present authors then used descriptive statistics and non-parametric Monte Carlo permutation tests to explore any differences in the DCRP measures between children with DS (n = 5) and ASD (n = 5). To examine whether children's emotional and behavioural problems decreased after the therapy, the present authors calculated differences between the CBCL scores before and after the intervention, for the whole group and separately for the children with DS and ASD.

3 | RESULTS

The present authors first performed a Monte Carlo permutation test to assess whether children's observed RR_{peak} in the first and final therapy session significantly differed from randomly generated values. This was the case for all children in our sample (all p-values < .01). The present authors then investigated whether the DCRP measures improved significantly between the first and last session of dog therapy (see Table 2).

3.1 | Proportion of synchrony

The proportion of synchrony represents instances when both child and dog are moving in the same direction at the *exact* same time. Nine children had a higher proportion of synchrony during the last therapy session compared to the first one. A repeated measures ANOVA shows this difference is statistically significant, with a high effect size ($F(1,9) = 11.81$, $p = .007$, 90% CI [0.03, 0.10], $\eta G^2 = 0.38$).

3.2 | Recurrence rate

The proportion of recurrence across the DCRP gives a more detailed view of the synchrony between the child's and dog's movements in the 30-s window around the line of synchrony. The recurrence rate increased significantly in the last therapy session, with a high effect size ($F(1,9) = 10.3$, $p = .011$, 90% CI [0.02, 0.06], $\eta G^2 = 0.37$).

3.3 | RR_{peak}

This measure represents the highest proportion of recurrent points found in the DCRP of the children. The difference in RR_{peak} between the first and last therapy session was statistically significant ($F(1,9) = 11.62$, $p = .008$, 90% CI [0.04, 0.12]), again with a high effect size ($\eta G^2 = 0.42$).

3.4 | Q_{los}

The Q_{los} measures show that during both sessions, children more often temporally led the dog than the other way around. During the final session, however, the asymmetry between child and dog appeared to be less ($M_{first\ session} = -0.13$, $M_{last\ session} = -0.07$). This difference just fell short of significance ($F(1,9) = 2.55$, $p = .07$, 90% CI [−0.01, 0.13], $\eta G^2 = 0.11$).

3.5 | Difference between children with ASD and DS

On average, the five children with ASD showed a greater increase in the DCRP measures over time, apart from the Q_{los} measure. This indicates more synchrony between children with ASD and their therapy dogs after six sessions, compared to the children with DS. However, none of the differences were statistically significant.

3.6 | CBCL measures

On average, the children showed a decrease in problem behaviour after the therapy sessions, as their parents indicated by lower scores on the CBCL scales internalizing problems, externalizing problems and the total problem scale (see Table 3). None of the differences were statistically significant. The children with DS showed a bigger decrease in the problem scales, compared to the children with ASD. This difference was not statistically significant.

4 | DISCUSSION

This study investigated synchrony between children with ASD or DS and their therapy dogs. The present authors compared patterns of

[1]The normality assumption was checked prior to performing the analyses. Nonetheless, because of the small sample size, the present authors also performed non-parametric Monte Carlo permutation tests, which confirmed our results.

TABLE 3 DCRP and CBCL measures for each child and overall

Child	Diagnosis	Session	Prop. Sync	Rec. rate	RR_{peak}	Q_{los}	CBCL intern. problems	CBCL extern. problems	CBCL total problems
1	DS	First	0.02	0.01	0.05	−0.20	18	5	40
		Last	0.06	0.03	0.12	−0.13	17	8	42
2	ASD	First	0.04	0.02	0.09	0.01	4	33	77
		Last	0.08	0.04	0.13	0.03	3	32	77
3	DS	First	0.03	0.02	0.07	−0.12	8	6	38
		Last	0.06	0.03	0.11	−0.16	4	2	18
4	ASD	First	0.03	0.01	0.06	−0.16	16	33	106
		Last	0.01	0.01	0.02	−0.05	16	35	110
5	DS	First	0.02	0.01	0.06	−0.11	2	2	14
		Last	0.05	0.01	0.09	−0.14	0	2	10
6	DS	First	0.02	0.01	0.04	−0.10	5	0	12
		Last	0.09	0.05	0.16	−0.09	1	0	3
7	ASD	First	0.05	0.01	0.06	−0.15	32	24	90
		Last	0.17	0.10	0.23	−0.04	24	24	79
8	DS	First	0.02	0.01	0.04	−0.36	17	20	74
		Last	0.05	0.03	0.08	−0.02	4	13	34
9	ASD	First	0.03	0.01	0.06	−0.13	8	18	61
		Last	0.14	0.10	0.20	−0.03	16	18	68
10	ASD	First	0.03	0.01	0.04	0.04	13	11	57
		Last	0.20	0.09	0.23	−0.04	13	12	62
Mean		First	0.03	0.01	0.06	−0.13	12.30	15.20	56.90
		Last	0.09	0.05	0.14	−0.07	9.80	14.60	50.30

synchronous movements during the first and final session of a six-week dog-assisted therapy (DAT) programme. Movement synchrony has been hypothesized as an underlying mechanism of animal-assisted therapies. The clear-cut way in which dogs communicate would enable children with ASD and DS to establish synchronous movement patterns, which they can later extend to human interactions (Martin & Farnum, 2002; Verheggen et al., 2017; Winnicot, 1986). This study is the first to investigate whether synchronous movement patterns between child and therapy dog increase over time during therapy. Given that the social problems of children with ASD seem qualitatively different from those of children with DS (DiGuiseppi et al., 2010), the present authors explored differences between the children in terms of synchrony during the therapy sessions.

The present authors used cross-recurrence quantification analysis (CRQA), which enabled us to operationalize synchrony between child and dog not only as matching movement patterns at the *exact* same time, but also across an interval of 30 s to accommodate for the response latencies of children with ASD and DS (Inui et al., 1995; Torriani-Pasin et al., 2013; Wallen & Walker, 2010; Welsh & Elliott, 2001). Results demonstrate a significant increase in synchrony of the movements of child and therapy dog during the sixth therapy session. Importantly, there was indeed not only an increase in synchrony at the exact same time, but also across an interval of 30 s around this point, and an increase in the highest proportion of recurrent points. The results also suggest an increase in the coupling between child and dog during the final session (lower Q_{los} measure), meaning that child and dog became more aligned (mutually attuned) in their movements. This last change in synchrony, however, just fell short of significance.

Previous studies on DAT have demonstrated a positive effect on self-esteem, communication and social interaction of children with ASD (Berry et al., 2013; Silva et al., 2011). Other research has shown that therapy dogs have a calming and de-arousing influence on children with DS (Esteves & Stokes, 2008; Limond et al., 1997). Although synchrony has been proposed as a possible mechanism underlying the positive effects of DAT, this study is the first to demonstrate an increase in synchrony during these therapy sessions. While the present authors did see the expected decrease in problem behaviour after the therapy, this was not statistically significant, which may be due to the small sample size. That said, the link between interventions to increase movement synchrony and adaptive behaviour has been established in other areas. For example, synchrony using dance and music has been associated with social bonding (Hagen & Bryant, 2003; Hagen & Hammerstein, 2009), and induced synchrony through movement has a positive effect on the extent to which partners trust each other, resulting in an increase in prosocial behaviour (Fessler & Holbrook, 2016; Leclère et al., 2014; Reddish, Fischer, Bulbulia, Bulbulia, & Huici, 2013; Stern, 2010; Tarr, Launay, Cohen, & Dunbar, 2015).

An interesting outcome is that children with ASD showed a bigger increase in synchronous movement behaviour during the final

therapy session, but a smaller decrease in their emotional and behavioural problems compared to children with DS, as reported by their parents. Although this was not statistically significant, a clear trend in the data could be observed. A reason for this might be that the impairments of children with ASD in social interactions are more severe than those of children with DS (DiGuiseppi et al., 2010). The children with ASD had significantly more problem behaviour at the start of the study compared to the children with DS (see Table 1). Indeed, research has shown that children with ASD are more "resistant" to human social interactions than children with DS (Adamson, Deckner, & Bakeman, 2010; Dawson et al., 2004), while other research indicates that children with ASD comprehend animal communication better than human communication (Prothmann, Ettrich, & Prothmann, 2009), which may explain their greater increase in synchrony with the therapy dogs.

4.1 | Limitations

The number of participants in this study calls for caution with respect to the generalizability of our findings. That said, the smaller number of participants did enable an in-depth investigation of the synchrony process during the therapy. Thorough analyses like these, that is, measuring synchrony across long time series of (coded) behaviours, are crucial to strengthen the clinical use of dog-assisted therapy, as it is not just essential to know *if* an intervention works, but also *how* it works (Brazil, Ozer, Cloutier, Levine, & Stryer, 2005). The small sample size of the current study did refrain us from calculating correlations between measures of behavioural problems and synchrony between child and therapy dog (cf. Schönbrodt & Perugini, 2013; Yarkoni, 2009). Future studies with considerably higher levels of statistical power can reveal important information about the association between child–animal synchrony in animal-assisted therapy and behavioural outcomes in daily life.

In this study, the present authors did not characterize the children in terms of their cognitive and social functioning and language use other than the scores of the CBCL on problem behaviours (CBCL; Achenbach et al., 2002). Although this questionnaire is widely used and research has shown that parents can adequately assess the behaviour of their children (Moretti & Obsuth, 2010; Warnick, Bracken, & Kasl, 2008), researchers have indicated that the three-point Likert scale of the CBCL (not true, sometimes true and often true) may limit the detection of change in behavioural problems over time (McClendon et al., 2011). The CBCL has also been criticized for only measuring children's emotional and behavioural problems, but not the presence or absence of prosocial behaviour (Dekker et al., 2002; Verhulst, Koot, & Ende, 1994).

Lastly, our study does not shed light on the minimum number of DAT sessions necessary to yield the most optimal results, while this has been indicated as an important avenue for future research (O'Haire, 2013). In the current study, some measures failed to reach significance, and it is unclear if this is due to the limited number of sessions (six), the sample size or another unknown factor.

4.2 | Future directions

Our study is the first to provide preliminary evidence that behavioural synchrony is a key mechanism contributing to the effect of DAT for children with ASD and DS. To further strengthen the knowledge base and to increase the generalizability of our findings, more research is needed. Apart from larger sample sizes, future studies could make use of advanced movement analyses involving technology such as movement tracking using sensors or optoelectronic cameras. In addition, an interesting avenue for future studies is to examine differences between typically developing children and children with ASD or DS while interacting with a dog. A comparison of these groups may provide us with more information about the specific patterns of behavioural (movement) synchrony between these children and therapy dogs, which may inform us about how the present authors can improve their communication and social interactional skills.

CONFLICT OF INTEREST

In accordance with the Journal of Autism and Developmental Disorders and our ethical obligation as researchers, the present authors are reporting that during the research, the first author was president of the SAM Foundation, a non-profit foundation offering animal-assisted interventions in the Netherlands for children with Down syndrome and children with autism spectrum disorder. The SAM Foundation may be affected by the research reported in the enclosed paper in a non-financial or non-commercial manner. By not interfering in data collection (carried out by professional therapists) and by having an independent third party to do the statistical analyses, the present authors believe that the present authors have done our utmost to secure scientific objectivity of design, procedures and results under all circumstances.

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