Soundbeam imitation intervention: Training children with autism to imitate meaningless body gestures through music

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Abstract

Purpose – *This paper aims to present the application and critical reflection on the effects of a intervention for children with autism spectrum disorder (ASD): the Soundbeam Imitation Intervention (SII). The intervention is based on the imitation of meaningless body gestures supported by a musical feedback. The rationale underlying SII is that mirror neurons deficit may represent the cause for the incomplete development of social and motor functioning in children with ASD. Following this assumption, it is possible to hypothesise that a systematic activation of this a system through the simultaneous observation-execution of meaningless body gestures may affect functional changes of mirror-related functions.*

Design/methodology/approach – *A sample of 14 children, who were between 5 and 9 years of age, with a diagnosis of ASD were involved in a six weeks' SII programme. The programme is designed as a three-step progression, where each step includes exercises that focus on an activity: synchronous/one arm imitation, synchronous/two arms imitation and delayed imitation. Exercises are based on repeated movements-melodies associations of increasing difficulty. Motor imitation and social attention were assessed using a synchronous video-modelling task pre and post intervention.*

Findings – *Data highlight significant improvements in imitation accuracy and duration of social sustained attention were achieved.*

Originality/value – *Data reported in this paper provide preliminary and promising evidence that imitation and social attention skills acquired through SII can be generalised to a video-modelling imitation setting. The SII ordinal execution has included meaningless gestures, usually excluded from previous interventions, and this adds further validity to the training.*

Keywords *Social skills, Music therapy, Imitation, Autism spectrum disorder, Mirror system, Motor skills*

Paper type *Research paper*

Introduction

Imitation difficulties are specific and extremely common in children with Autism Spectrum Disorder (ASD) (Barbaro and Halder, 2016; Chetcuti *et al.*, 2019; Williams *et al.*, 2004). This symptom is so relevant that imitation delays are considered valid predictors of this disorder (Miniscalco *et al.*, 2014; Vanvuchelen *et al.*, 2011), and a severity score linked to this very symptomatology, introduced by Gotham *et al.* (2009) as assessed through the Autism Diagnostic Observation Schedule (Hus *et al.*, 2014; Rogers *et al.*, 2003), has been found to be significantly related to imitation deficits (Gallese *et al.*, 2004) in social response to cues. The capability of imitating others is thought to be critical for the development of social skills and language (Ingersoll, 2012; Rizzolatti and Arbib, 1999; Suddendorf *et al.*, 2013; Tettamanti *et al.*, 2005; Tomasello *et al.*, 1993; Zambrana *et al.*, 2013), which are noticeably impaired in ASD. Given that imitation has a special role also in motor development (Filippi *et al.*, 2016; Maratos, 2017; Mari *et al.*, 2003), soft motor signs and developmental

deficiencies shown by children with ASD (Fabbri-Destro *et al.*, 2009; Forti *et al.*, 2011; Glazebrook *et al.*, 2006; Gowen and Hamilton, 2013; Lloyd *et al.*, 2013; McDuffie *et al.*, 2007) could be related to difficulties in learning movements through imitation (Biscaldi *et al.*, 2014).

On these grounds, several interventions based on imitation have been designed over the years. These interventions are aimed at addressing a core feature of ASD and indirectly improving social skills (Koehne *et al.*, 2016; Lindsay *et al.*, 2013; Rogers *et al.*, 2003; Sanefuji and Ohgami, 2013; Small *et al.*, 2012) through a possible activation of the mirror neuron network associated in the motor cortex (Catmur, 2013; Hamilton, 2013; Iacoboni *et al.*, 1999). The reason why mirror neuron network is assumed as relevant for the efficacy of these interventions is because the mirror neurons theory implies that reciprocal imitation is necessary for activation of the mirror system (Fadiga *et al.*, 1995; Grèzes *et al.*, 2003; Hamilton, 2015; Iacoboni *et al.*, 2001; Mashal *et al.*, 2012; Sperduti *et al.*, 2014). This theory also implies that mirror neurons allow individuals to assimilate other people's actions into their own motor schemas (Iacoboni *et al.*, 2001; Keller *et al.*, 2014; Oberman *et al.*, 2008), they are ought to represent the basis for communication (Iacoboni *et al.*, 2001; Rizzolatti and Arbib, 1999; Rizzolatti and Sinigaglia, 2016). Dysfunctions in the mirror function in individuals with ASD have been confirmed by a large body of evidence (Dapretto *et al.*, 2006; Gallese *et al.*, 2013; Hadjikhani *et al.*, 2007; Hamilton, 2013; Martineau *et al.*, 2010; Oberman *et al.*, 2008). These specific dysfunctions have been found correlate significantly with the severity of symptoms (Williams and Happé, 2010) and have been related to social and imitation deficits (Iacoboni, 2009a; Kolb and Gibb, 2011).

Aa experiential habituation can lead existing neurons to change their synaptic connectivity (Sweatt, 2016), the functioning of the mirror network might be improved by activities based on imitation (Perkins *et al.*, 2015; Yuan *et al.*, 2015). Imitation can be used as the mirror neuron exercise by definition and by eliciting the visual, auditory and proprioceptive canals at the same time (Iacoboni *et al.*, 1999), the activation of the mirror neuron network might be maximised. Treatments based on imitation are considered potentially effective both by the Scottish Intercollegiate Guidelines Network (2007) and by the Italian National Guidelines System for treatment of ASD-related disorders in children and adolescents (Ingersoll and Schreibman, 2006). A good example of this type of intervention is the Reciprocal Imitation Training (RIT) developed by Ingersoll and her collaborators (Ingersoll, 2010, 2012; Ingersoll and Gergans, 2007; Ingersoll and Lalonde, 2010; Ingersoll *et al.*, 2007; McDuffie *et al.*, 2007). RIT is an intervention based on object-related actions and meaningful gestures. The gestures included in the intervention can have conventional (e.g. "Where is it?": palm upturned) and affective meanings (e.g. "Oh, no!": hands on face) or can describe objects (e.g. "Airplane": arms out), attributes (e.g. "Big": raise arms) or actions (e.g. "Spin": finger on circle). RIT was proved to be effective in increasing the quality of both spontaneous and elicited imitation with the adaption of Unstructured Imitation Assessment. This intervention was proved to be effective to teach spontaneous object imitation (Ingersoll *et al.*, 2007) and gesture imitation (Ingersoll and Lalonde, 2010) in children with ASD, resulting also in improved language, play and joint attention skills (Ingersoll and Gergans, 2007). However, trials carried out with RIT involved actions which were too narrow to allow to generalise the findings and use the intervention as a standardised one.

The studies aforementioned support the notion that interventions grounded on reciprocal imitation can be effective for children with ASD. It is also important to highlight that the difficulties shown by these children are more evident and severe when they imitate meaningless body gestures, rather than actions with objects, such as those trained in RIT (Hamilton, 2008; Vanvuchelen *et al.*, 2007). Indeed, the imitation of meaningless body gestures seems universally impaired in children with ASD. On the contrary, the imitation of meaningful gestures is impaired in low functioning ASD only (Ingersoll *et al.*, 2012). This suggests that different forms of imitation (e.g. object, gesture, vocal) may be intended as

independent dimensions, as there is evidence that children with ASD only generalise within the imitation category they have been trained to (Hamilton, 2008), although some studies (Gallese et al., 2004; Wild et al., 2010) reported correlations between different imitative behaviours (even if meaningless gestures were not considered or were largely under-represented in these studies).

If the assumption of the exitance if independent "imitation dimensions" is true, only an intervention based on the imitation of meaningless body gestures may address the core difficulty of children with ASD (Molnar-Szakacs and Heaton, 2012). However, achieving this goal is extremely problematic for children with ASD, given the lack of social interaction and their reduced sustained attention. Imitating meaningless movements has little or no tangible effect on the physical world and the lack of such feedback makes this kind of imitation particularly demanding. In addition, the lack of relation with a semantic/social meaning of the action prevents children to sustain attention during the training phase. Technological devices allowing individuals to receive feedbacks in response to meaningless actions might permit to overcome these limitations.

Soundbeam Imitation Intervention (SII) belongs to this category of devices. It consists of an ultrasound-to-midi converter (Soundbeam 5®, Soundbeam project, UK) to associate sounds to body movements during imitation. Using this system, sounds work both as immediate feedbacks for accuracy in imitation and as a reinforcement to sustain attention. The sequencing of sounds allows to generate melodies quite easily. It has been reported that music represents an attractive and motivating stimulus for children with ASD (Jones, 2018; Lord et al., 2000; Reschke-Hernández, 2011) and might even facilitate mirror activation, given a partial overlap of music processing areas with the mirror network (Antonietti and Colombo, 2014; Colombo et al., 2013; Trevarthen and Daniel, 2005). This further supports the idea that a musical feedback could make an intervention based on the imitation of meaningless body gestures feasible for these patients. Soundbeam-based interventions have been reported to have a positive effect on improving communication and fostering positive emotion in children with different disabilities (Lee, 2015) as well as motor skills and attention span (Lee, 2011), even if it has not been used (to our knowledge) with children with ASD.

Starting from the evidence discussed above, we were expecting to be able to record significant improvements in imitation abilities and sustained attention in children with ASD who were involved in the SII.

Method

Participants

Fourteen children (12 boys and 2 girls), age range 5 to 9 years (M = 7.6; SD = 0.9), participated to the study. All participants had a diagnosis of ASD according to the DSM5 criteria and the Autism Diagnostic Observation Schedule (Lord et al., 2000) (see Table 1 for participants' characteristics) and had previously received TEACCH/ABA interventions for at least 12 months at the centre where SII took place. All participants were right-handed. During SII, they continued with their regular school programmes but were not engaged in any other new treatment. All legal guardians gave their informed written consent prior to the children's participation. The study was approved by the ethics board of the IRCCS "Eugenio Medea", in accordance with the Declaration of Helsinki.

Children underwent cognitive level evaluation through Wechsler Preschool and Primary Scale of Intelligence Test (WPSI) (Wechsler, 2012) or Wechsler Intelligence Scale for Children (WISC–III R) (Wechlser, 2006): IQ ranged from 44 to 96 (M = 77.4; SD =15.5), with lower verbal IQ (27 to 79; M = 55.8; SD = 14.3). Two children were unable to produce any intelligible word and not evaluable at standardised cognitive tests. All participants also scored below the 1st percentile at the Movement Assessment Battery

Table 1 Participants' details and training programme

Gender	Age	TIQ[*]	VIQ[**]	PIQ[***]	Sessions	Level
M	5.9	53	50	56	12	4
M	6.1	78	27	46	10	4
M	6.4	71	73	76	12	4
M	6.5	77	41	103	12	2
M	6.9	44	56	44	10	3
M	6.9	82	79	90	11	6
M	6.9	96	46	50	12	15
M	6.9	n/a	n/a	n/a	9	3
M	7.2	60	43	69	10	1
F	7.1	n/a	n/a	n/a	12	2
M	7.4	57	47	75	12	2
F	7.5	80	45	121	12	5
M	8.6	71	64	85	12	8
M	9.11	70	62	83	12	13

Notes: The table reports the participants' gender, age (years and months) and cognitive level [*]TIQ = total IQ; [**]VIQ = verbal IQ; [***]PIQ = performance IQ), the number of attended SII sessions and the final level attained in the progression of SII exercises. Two participants could not be evaluated for lack of collaboration or comprehension of instructions

for Children (Brown and Lalor, 2009; Croce *et al.*, 2001; Jones, 2018), which identifies, describes and guides treatment of motor impairment.

Materials

Both motor imitation and social attention were assessed using a synchronous video-modelling task. In this procedure, participants were required to play a drum copying a model shown on a video. The child was asked to sit in front of a bongo drum. Behind the drum, the video was played on a 15" laptop PC placed on a height-adjustable desk (Figure 1).

The video started with an initial "beep" to alert the participants and focus their attention. For the first 10 s, they were asked to watch the video, where a musician was shown while playing the same kind of drum, by repeating two strokes with the left hand and one stroke with the right hand, at a slow rhythm (Figure 2). After a second "beep", participants were asked to copy the musician's actions on their drum while keep watching the video where the player was still hitting the drum. They were encouraged to carry on playing for 60 s.

Through motion capture, motor imitation was precisely measured in terms of accuracy. Both the child's and the player's hand movements were captured by eight infrared motion
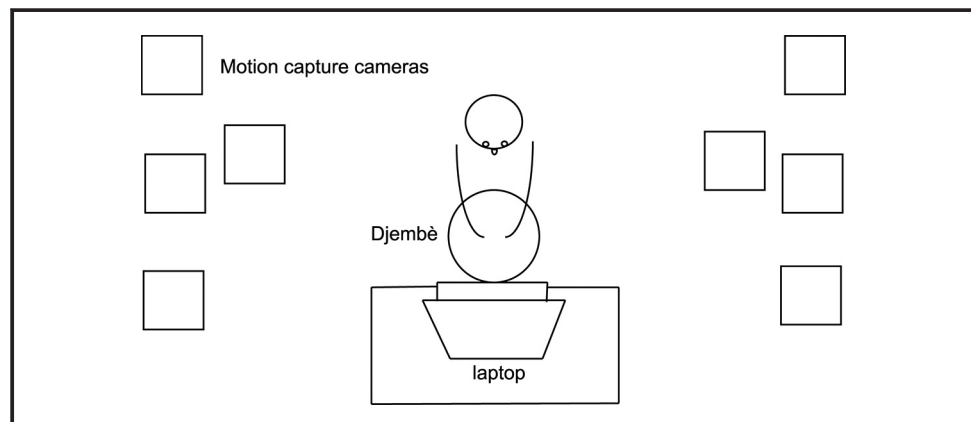
Figure 1 Video-modeling setting

Figure 2 Rhythm used in video modeling assessment

capture cameras at 60 Hz (manufactured by S.M.A.R.T. BTS, Milan), located four on each side, at 2.5 m from participants (Figure 2) and by recording two passive 1-cm markers attached to the dorsum of each hand. A point-by-point Pearson's correlation between the child's and the model's movements returned an indicator of motor imitation accuracy over the 60 s.

Sustained social attention was measured through the analysis of video recordings performed by two independent researchers. The amount of time during which participants were looking at the video returned an indicator of sustained social attention.

Procedure

The intervention was designed as 12 individual SII sessions of 30 min each, ran biweekly over a six weeks' period. Some children could not attend all the sessions, due to school vacations or illness: Average attendance per child were 11.2 (Table 1). The intervention was built considering this possibility, so the effectiveness of the training was not affected by missing one session. Imitation and social attention assessment, mentioned below, took place one week before the start and one week after completion of the SII programme.

SII is designed as an individual intensive intervention in a progression of imitation exercises of arm movements (up and down) of a model-player standing in front of the child (Figure 1). The three steps of the progression were synchronous/one arm imitation, synchronous/two arms imitation and delayed imitation. Exercises are based on repeated movements-melodies associations of increasing difficulty.

Interventions took place in a dedicated lab with one experimenter and a technician. Soundbeam5® (Soundbeam project, UK), shaped as a red plastic microphone, allows a sound feedback each time one's own hand is moved in front of the sensor. The sequence of generated sounds can be pre-programmed. Hence, repeated movements made it possible to play a pre-defined melody.

Two Soundbeam5® were used in our SII: one for the participant and one for the trainer. Although they were programmed on the same familiar, different tunes (namely, different timbres corresponding to the different musical instruments) were used to avoid boring effects due to the presentation of the same kind of tunes.

SII sessions were designed as a series of steps whose progression was individualised and regulated by the acquisition of competencies measured by two consecutive trials on the same exercise: The participant would progress to the next step if he/she made no mistake in either trial. In the first two exercises, participants were asked to play the melody with the Soundbeam5® by moving hands together with the trainer (synchronous imitation): Exercise 1 focused on the right arm; Exercise 2 involved both arms, although they were moved one at a time in a randomised order. The trainer regulated the movement-melody rhythm on the basis of the child's promptness to imitate. If one movement was not imitated properly or at all, the trainer would sing a tune to get and refocus the child's attention and then repeat the movement. During Exercise 3, participants were asked to play the melody alone,

immediately after it has been modelled and demonstrated by the trainer (delayed imitation) using the right hand.

Once the three exercises were assimilated for a melody, they were repeated with a more difficult melody. Difficulty was manipulated both in terms of familiarity and in terms of rhythm complexity. The progression of melodies was as follows:

- familiar children song/rhythmically easy: "Frère Jacques";
- familiar children song/rhythmically difficult: "Happy birthday";
- unfamiliar rhythm/rhythmically easy: "We will rock you" chorus by Queen; and
- unfamiliar melody/rhythmically difficult (purposely composed).

Results

Data analysis

Given that the progress in SII steps was individualised according to the child's acquisition of imitation competences, first the SII step achieved at the end of intervention was correlated with participants' age and IQ. Predicting a positive association, one-tailed tests were used.

Pre- and post-intervention comparisons were computed for imitation accuracy and social sustained attention at the video modelling imitation task. Comparisons included 13 out of 14 participants because one child refused post-intervention assessment. Results were not affected but this, as the overall sample size did not change greatly, and all the sessions were run with one child at the time.

Imitation accuracy was indicated by Pearson's correlations between the participant's movement and the trainer's movement, which was shown on the video. After the motion-capture phase, data were synchronised with video recordings, analysing the left hand and the right hand separately. Given the small sample size, for pre-post comparison of imitation scores the non-parametric paired Wilcoxon Signed Rank Test was used. Additionally, standardised effect size (Cohen's d) was calculated to weight the analysis of possible differences. Gains in imitation were examined in relation to participants' characteristics: Pre-intervention child-model correlation scores were subtracted from post-intervention correlations, yielding a change score for each participant. Bivariate correlations were calculated between these scores and the child's age and IQ. Also, because the left hand was only trained in Exercise 2, possible hand differences in improvement were measured by a mixed (2×2) ANOVA, having hand (left vs right) as between-subjects factor and the pre-post correlation difference as within-subjects factor.

Social sustained attention was assessed by the total time during which children attended the task by looking at the video. This was derived by the analysis of video-recording, after the total time duration was divided into 5 s sections. The number of sections where the participants looked at the video (attended sections) was compared between the pre and post intervention phases with McNemar's chi square test. Also, we examined whether pre-intervention child characteristics were predictive of gains in attention: the number of pre-intervention attended time sections was subtracted from the number of post-intervention attended ones, yielding a change score for each participant. These change scores were then examined in relations to child's age and IQ through bivariate correlations.

Results

The level of attendance (computed as the number of sessions the patient participated to) did not correlate significantly with IQ ($r = 0.22$; $p > 0.05$) and age of participants ($r = 0.25$; $p > 0.05$).

Therefore, all participants were included in the analyses regardless the number of SII sessions attended. The analysis of the association between child-related characteristics and the step achieved in SII retuned a moderate correlation with participants' age ($r = 0.65$; $p < 0.05$) and, somehow, with IQ ($r = 0.54$; $p = 0.07$).

Focusing on imitation accuracy, at pre-intervention assessment correlations between the participants' and the model's movement were low (M = 0.33; SD = 0.16). At post-intervention assessment the degree of child-model correlations improved for 9 out of 13 participants (69%). On average the correlations increased to 0.44 (SD = 0.20). Pre-post difference was significant at signed rank test ($Z = -2.70$; $p < 0.01$), with a very large effect size of 1.02. Gains in imitation were not associated to age and IQ ($r = 0.29$ and $r = -0.23$, respectively; both $p > 0.05$). No significant hand differences emerged ($F(1,24) = 1.60$; $p > 0.05$). (Figure 3).

Focusing on social sustained attention, 6 children out of 13 did not fully pay attention during the pre-intervention assessment. On average, children did not pay attention to 68% of the tasks (M = 8.16, SD = 2.40). During the post-intervention assessment, only one participant did not pay attention during the whole task. On average, during the post-test phase, children payed attention to 97% of the tasks (M = 11.64; SD = 1.40). Pre-post difference was significant at McNemar chi-square test ($p < 0.001$). Such gains in attention were not associated with the participants' age and IQ ($r = 0.37$; $p > 0.05$ and $r = 0.41$; $p > 0.05$, respectively).

Discussion

The current study reports data supporting the validity of a new intervention for school-age children with ASD, called Sound Beam Imitation Intervention (SII), which is based on the imitation of meaningless body gestures aided by musical feedback.

Imitation can assume several shapes (Eckerman, 2017; Iacoboni, 2009b): oral-facial imitation, actions (with or without objects) and gestures (symbolic or meaningless). The question whether such abilities are moderately separate and unrelated or, rather, depend on a unitary general imitation ability is still controversial (Maratos, 2017). However, meaningless gestures are particularly difficult to be trained in imitation, in particular with children with ASD, given their difficulties in sustained social attention. These gestures produce neither physical effects that may act as feedback for imitation nor semantic effects that may help sustaining attention.

Effectiveness of the intervention has been evaluated for imitation accuracy and sustained attention, both assessed at a video-modelling task. During that part of the intervention, participants were required to imitate a player who was shown while playing a drum on a video. Imitation accuracy was measured as the child-player Pearson's correlation in the

Figure 3 Imitation skills pre and post SII intervention
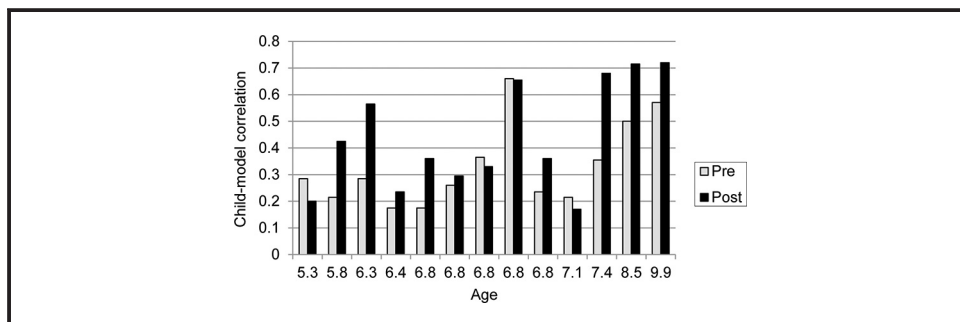
movement frequency. After the SII, imitation increased from 0.33 to 0.44, with a very large effect size of 1.02. Social attention was measured as the time interval children focused on the video. After the SII intervention, attention improved from 68 to 97% of total time sustained. Older children made progresses faster during SII exercises and participants with higher IQ were somewhat facilitated. These results confirm to some extent a positive relationship between developmental skills and growth during treatment that has been previously suggested (Kraemer and Kupfer, 2006; Swallows and Graupner, 2005). Despite this relationship, in our study gains in imitation and attention skills were similar for all children. Because of this reason, SII might can be considered a valid intervention for children with ASD between five and nine years old. Also, SII might be a potentially viable intervention for children with ASD with severe mental retardation and even one of the few for non-verbal patients.

Another interesting aspect of the present study is that SII focuses not only on meaningless gestures but also on simultaneous, rather than delayed, imitation. Thus, SII might address a specific timing and coordination deficit found in children with ASD, evident both in imitation settings and in other areas, such as gait (Anzulewicz et al., 2016; Dawson and Watling, 2000; Kindregan et al., 2015; Nobile et al., 2011; Smits-Engelsman et al., 2013; Xavier et al., 2018).

As it has been suggested (Bauman, 2010; Colombo and Lecciso, 2019; de la Torre-Ubieta, Won et al., 2016), the selection of appropriate therapy for ASD should ultimately depend on knowledge of the underlying biology. Our approach is based on the hypothesis that mirror neurons deficit may represent the cause for the incomplete development of social functioning in children with ASD and that a systematic activation of such system through the simultaneous observation-execution of meaningless body gestures may effect functional changes of mirror-related functions. Movements represent the basis for inter-individual communication and the development of speech when considered with mirror neurons (Rizzolatti and Arbib, 1999; Tettamanti et al., 2005). In fact, neural interactions between movement and language have been reported (Bonacina et al., 2015; Mollo et al., 2016; Rizzolatti and Arbib, 1999), and there is high comorbidity for movement and language deficits (Arbib, 2008; Iannuzzi et al., 2016; Stone and Yoder, 2001). Imitation abilities of children with ASD are strictly related to language skills (Lobban-Shymko et al., 2017; Toth et al., 2006).

Conclusions

This study, even if presents interesting and promising data, also has some limitations, including a small sample, and the fact that a few children missed one of the sessions. Behavioural interventions to teach imitation to children with ASD based on highly structured, adult-directed and artificial reinforcement have been criticised for the inability to produce generalised spontaneous imitation that maintains in absence of reinforcement (Ingersoll and Gergans, 2007; Rogers et al., 2017; Wang and Krata, 2017). Nevertheless, our data provide some preliminary and promising evidence that imitation and social attention skills acquired through SII can be generalised to a video-modelling imitation setting.

Compliance with ethical standards

- disclosure of potential conflicts of interest: the authors declare no potential conflict of interest;

- research involving Human Participants: the study was approved by the ethics board of the IRCCS "Eugenio Medea", in accordance with the Declaration of Helsinki; and

- informed consent: all legal guardians gave their informed written consent prior to the children's participation.

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