University of Messina

ISSN 2612-4033

Journal of Clinical & Developmental Psychology

Journal homepage: http://cab.unime.it/journals/index.php/JCDP/index

The Mirror Protocol for teaching generalized Imitation in six children with Autism Spectrum Disorder

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ABSTRACT

Background: Generalized Imitation is a higher-order ability that enables an individual to imitate novel behavior without extrinsic reinforcement. With this capability, children often learn by seizing natural daily opportunities. It is different, however, for children with Autism Spectrum Disorder (ASD) because the criticality of their imitative repertoire limits the learning modes and opportunities. The main objective of this research is to contribute to the validation of the Mirror Protocol, where the teaching of imitated motor actions through the mirror can foster the emergence of Generalized Imitation

Methods: We designed a single-subject study with a sample of six children with ASD to investigate the acquisition of this capability. We conducted a pre-probe to assess the presence of generalized Imitation across three types of actions: gross motor actions, vocal actions, and circle time dances. The children were not exposed to these actions afterward to prevent learning effects. Following this, we implemented a training period focused on teaching gross motor imitation (GMI) using a mirror. Finally, we conducted a post-probe phase, replicating the same tasks from the pre-probe to assess whether the children had acquired generalized Imitation.

Results: Since none of the participants met the criterion for all three variables, we could not confirm the acquisition of generalized Imitation. However, analyzing the individual performances shows an upward trend for five out of six participants.

Conclusions: These results, although limited, contribute to the literature on the efficacy of the Mirror Protocol, which facilitates the emergence of a fundamental capability for the growth and learning of children with ASD.

Keywords: Mirror Protocol; Generalized Imitation; Autism

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https://doi.org/10.13129/2612-4033/0110-5074

Introduction

Imitation is a psychological construct that has been defined and debated for many years in literature and is still studied today. Greer and Ross (2008) describe this ability using the "see-do" relation, which involves reproducing an observed behavior with a point-by-point action correspondence. In 2009, Greer and Speckman further contributed to this definition, believing that the conditional reinforcement of the correspondence between the observer's behavior and the observed emits Imitation.

Piaget's (1951) and Skinner's (1953) analytical-behavioral theories on the development of Imitation emphasized that Imitation is a learned ability acquired through experience during development rather than an inherited trait. More recently, neuropsychological researchers have supported theoretical hypotheses about Imitation by identifying neurons that activate when a person observes and performs the same motor actions (Rizzolatti, 2005). Researchers have defined these neurons as Mirror Neurons because of their function, which involves understanding motor actions performed by others and reproducing actions already present in one's repertoire (Rizzolatti, 2005).

These are just some of the main theories that have attempted to explain the complex phenomenon of Imitation. Although there may be disagreements derived from scholars' theoretical imprints, all agree on the importance of Imitation in human development (Moreno, 2012).

In typical development, Imitation of simple motor and vocal behaviors emerges at around six months, while an actual imitative repertoire, increasingly complex, develops by the age of two years, thus including the Imitation of fine-motor actions and actions with objects (Jones, 2007). From 12 months onwards, imitative responses become increasingly complex and require careful and continuous observation of the reference adults, who serve as models to be accurately replicated (Greer & Ross, 2008; Greer & Speckman, 2009); the accuracy of responses (motor and verbal) is refined through trial and error until a point-by-point correspondence with the observed model is achieved (Wilczewski, 2022).

Evidence on imitation points to its critical importance in social (Carpenter, 2006; Meltzoff, 2007), linguistic (Ross & Greer, 2003; Tsiouri & Greer, 2003; Tsiouri & Greer, 2007), cultural (Carpenter, Akhtar, & Tomasello, 1998) and play behavior learning (Fiese, 1990; Uzgiris, 1990).

A meta-analysis of 53 studies conducted by Edwards (2014) highlights the difficulties found in children with Autism Spectrum Disorder (ASD) in imitative skills compared to peers with typical development. Researchers have identified deficiencies in several response classes, including orofacial imitations, gross motor imitations, and object imitations. Although imitative difficulties are not

peculiar to all children in the spectrum, the limited repertoire frequently found in these children has knock-on effects on their learning ability (Edwards, 2014).

Closely related to Imitation is Generalized Imitation, defined as a higher-order ability that allows an individual to imitate novel behaviors without previous reinforcement related to the response itself (Catania, 2007; Keohane et al., 2008).

All researchers agree in distinguishing between Imitation and Generalized Imitation, with the former referring to a class of responses that includes directly taught individual social agents and the latter as a broader class of responses that encompasses imitative skills acquired without direct instruction (Moreno, 2012). An individual who has not acquired Generalized Imitation cannot imitate actions without direct instruction, including explicating the relevant contingencies and reinforcement or correction of the emitted response (Catania, 2007). Indeed, Generalized Imitation is only acquired when the internalized reinforcement of the correspondence between seeing and reproducing a behavioral pattern maintains the frequency of its use (Greer & Speckman, 2009).

Greer and Speckman (2009) define Generalized Imitation as a higher-order operant (or capability), meaning that, once acquired, it allows one to contact previously untapped learning modalities and opportunities. Generalized Imitation fosters natural learning opportunities, enabling children to observe and acquire behavioral patterns (Greer & Ross, 2008; Greer & Speckman, 2009). This process allows typically developing children to engage with games functionally (Wilczewski, 2022) and develop verbal behaviors. Such behaviors rely on essential prerequisites, including joint attention, an imitative repertoire (Greer, 2020), and object play, which children internalize without the need for contingencies or explicit instructions (Poon et al., 2012). Children with ASD present difficulties in all these skills, which is why they fail to take advantage of natural learning opportunities; usually, social agents or caregivers should directly instruct ASD children and shape them for specific prerequisites to emerge (Greer, 2002).

All successful interventions that have targeted imitative skills have used a wide range of strategies, such as prompting, reinforcement, visual cues, video modeling, peer modeling, and contingent Imitation (Caldwell, 2020). We can classify these strategies as Traditional Behavior Intervention (TBI), based on the principles of Applied Behavior Analysis (ABA; Baer et al., 1967; Lovaas et al.,1967; Metz, 1965) or a Naturalistic Developmental Behavioral Intervention (NDBI; Schreibman et al., 2015).

Pereira Delgado et al. (2009) demonstrated that using a mirror can facilitate the emergence of Generalized Imitation in children with ASD by enhancing the perception of movement correspondence. Their study included a pre-test to assess the absence of Generalized Imitation, a mirror-based training phase, and a post-test to evaluate skill acquisition.

Several studies have replicated these findings, including Du (2011), Moreno (2012), Du & Greer (2014), Miller et al. (2015), Wilczewski (2022), and Scattolin et al. (2021). These studies primarily focused on preschool children with ASD, classified as Pre-Listeners.

Du (2011) replicated the procedure with a control group that did not use the mirror, confirming significant differences in Generalized Imitation acquisition between the experimental and control groups. However, Avelar (2017) reported conflicting results, as two participants did not acquire Generalized Imitation, and one showed better outcomes without the mirror. This discrepancy may be due to the child's maladaptive interactions with the mirror, such as stereotyped behaviors and distractions, which hindered learning.

Among the most recent contributions, two notable studies by Scattolin et al. (2021) and Wilczewski (2022) further explored the relationship between imitative skills and the acquisition of verbal behaviors, such as echoic responses.

Consistent with previous literature, several studies (Pereira Delgado et al., 2009; Du, 2011; Moreno, 2012; Du & Greer, 2014; Miller et al., 2015; Wilczewski, 2022; Scattolin et al., 2021) confirmed that participants acquired Generalized Imitation and were able to reproduce gross motor actions they had never observed before.

The acquisition of this capability has significant implications for children's learning. Since they do not require external reinforcement for imitated actions, they can benefit from more natural learning opportunities without relying solely on direct instruction (Greer & Ross, 2008; Greer & Speckman, 2009).

These studies further demonstrate that Imitation generalizes not only to gross motor actions but also to other domains. Researchers have observed that children can transfer imitative skills to fine motor actions, object manipulation, structured actions applicable in daily life, group-based activities, and even orofacial and verbal behaviors (Moreno et al., 2015; Scattolin et al., 2021; Wilczewski, 2022).

Furthermore, the literature suggests that imitating actions with objects is closely related to functional play, which represents a primary learning channel for children (Scattolin et al., 2021; Wilczewski, 2022). Additionally, research highlights that a well-developed imitative repertoire is a crucial prerequisite for the emergence of verbal behavior (Poon et al., 2012; Scattolin et al., 2021; Wilczewski, 2022).

This study aims to expand the literature on the Mirror Protocol by further investigating its effectiveness in promoting the acquisition of Generalized Imitation, building on these findings.

Method

Participants

We studied six preschool children aged between 3 and 5 years. The participants had a diagnosis of Autism Spectrum Disorder, formulated according to the diagnostic inclusion criteria of the DSM-5 (American Psychiatric Association, 2013). They attended a learning center that provided ABA-based therapy in northern Italy.

The children possessed different characteristics and verbal development (Greer & Ross, 2008), and we identified them by using the letters of the alphabet to protect their privacy.

Participant A was a three-year-old child of Pakistani origin in the Pre-Listener stage, as he could not respond to simple and direct instructions. The child had never had ABA therapy before entering the center and showed no interactions with adults, while he often approached peers with interest. He usually presented hetero-harmful behaviors (scratching and biting), and mand and vocal behaviors were absent. There was no presence of imitative behavior in any context of life. He had two therapies, two hours each, at the center every week.

Participant B was five years old and of Nigerian origin. His verbal development was categorized as Listener, achieved through the year of ABA therapy at the Intandem Center, where he had two weekly therapy sessions. The child could carry out simple instructions during the pre-test while sitting at the table. Functional interactions with adults to obtain reinforcers were present, while spontaneous interaction with peers was scarce. Vocal behaviors were absent. At the beginning of the research, participant B could imitate simple motor actions (clapping hands, tapping feet, touching belly, touching head, touching the table) while sitting in front of the therapist in a structured context. During the observation at school, we noticed the child's emerging interest in peer movements when songs were danced and sung.

Participant C was a four-year-old girl of Ukrainian origin. We considered her a Speaker in terms of verbal development, as she could formulate a few words in Italian and Ukrainian to manipulate the environment around her. The child had never had ABA therapy and was, together with Participant A, placed at the Intandem center, where she had two therapy sessions per week. She immediately showed little interest in social relationships and responded with problem behaviors such as screaming and crying when faced with easy requests. She carried out simple imitations such as clapping her hands and touching her belly, always with the help of "hand on hand" prompts.

Participant D was another three-year-old girl of Italian origin, classifiable as a Listener. Also, a newcomer to the center, she had two ABA therapy sessions per week. Avoidant to requests at the

table and in a natural context, the only imitative skills demonstrated were clapping hands, stamping feet, and touching the head.

Both participants C and D showed apparent compliance problems, and they were also included in the research to highlight the effectiveness of the Mirror Protocol in providing intrinsic reinforcement, making the activities' performance more stimulating.

The last two children, identified as participants E and F, were four and three years old, respectively. The former had just arrived at the center, while the latter had been receiving ABA therapy for one year. Participant E had two weekly therapy sessions, while F had only one. Both had a level of verbal development that could be categorized as Speakers, although not vocal. They possessed excellent interpersonal skills and good compliance. Like other participants, they also showed simple imitative skills (clapping hands, belly touching, tapping feet, head touching), but only when prompted by therapists in a 1:1 context.

We included Participant F in the research with the additional aim of observing an improvement in the topography of the Imitation, which had been hitherto not clean due to motor dyspraxia.

Dependent variable

We chose three dependent variables for the study because the research aims to observe whether imitative training with the Mirror Protocol favored the generalization of skills in several contexts and with different modalities. Therefore, the first variable chosen is the ability to imitate gross motor actions (GMI), never performed before, in a 1:1 ratio with the child sitting in front of the therapist; the second dependent variable is the ability to vocally imitate sounds with increasing articulation (vowels/syllables/words); while the last is the ability to imitate two dances during a circle time shared with peers.

We investigated each variable using a cold test at two separate points: before the start of treatment (pre-probe) and after the training had ended (post-probe). The children were not exposed to the dependent variables during the experimental phase to avoid a possible learning effect.

Independent Variable

The independent variable in this study is the Mirror Protocol, i.e., training in teaching imitative actions with the aid of a mirror. According to the literature, the mirror can benefit Imitation because it makes every body part observable, allowing immediate feedback on the correspondence between the produced movement and the previously observed one. In this way, children could achieve higher imitative accuracy, as well as become a source of reinforcement (Pereira Delgado, Speckman, &

Greer, 2009; Du, 2011; Moreno, 2012; Du & Greer, 2014; Miller et al., 2015; Wilczewski, 2022; Scattolin et al., 2021).

For the training, we chose 33 gross motor actions (GMI) of varying difficulty to teach using the mirror, and we divided them into 11 sets of three actions each. The actions chosen for training differed from those used for probing.

Research hypotheses

The central hypothesis of the research is that the imitation of gross motor actions (GMI), taught through the Mirror Protocol, can bring out generalized imitation in participants, which is a fundamental capability in the process of growth and continuous learning. We investigated the acquisition of this cusp in three different contexts: in motor actions imitated in a 1:1 ratio with the therapist, in the imitation of vocal actions, and in the imitation of dances during circle time with peers.

Material and Setting

We conducted this research at the learning center in northern Italy during the participants' therapy hours. To measure the dependent variables in the probing phase, we made paper data sockets indicating the motor and vocal actions children should have imitated. We mark "+" in case of correct imitation and "–" for an incorrect or absent response. The therapists had to present the desired action once and ask the child to imitate it and did not present any corrections for incorrect answers.

For measuring the GMI, a list of 20 motor actions (Table 1 in the Appendix) was created, with the respective movement description and the accepted variation, given the participants' competence gaps.

For the measurement of vocal actions, a data set similar to that for GMI was created (Table 2 in the Appendix), and it included three types of actions, differing in difficulty: (a) five prolonged vowel sounds (A-E-I-O-U); (b) five simple syllabic sounds (MA-CA-PE-LU-SO); (c) five simple, high-frequency syllable words (MOUSE-ONE-HOUSE-APPLE-AWAY).

We created an additional data sheet to describe the movements and the accepted variations (Tables 3 and 4 in the Appendix) for measuring the two ballets performed in circle time. The songs "Ci son due coccodrilli" and "La zia di Forlì" were chosen. We specially created simpler movements than the original ones.

We conducted two probe sessions during the pre-test and post-test phases, with a mastery criterion set at 90% correct answers. Regarding the training phase, we created 11 gross motor actions (GMIs), each consisting of three actions for 33 GMIs. The Appendix (Table 5) contains all the sets used. Children carried out GMIs according to their abilities. We considered the training phase completed if a child could perform all of them. It was advisable to start from a Set of actions already known or

within the child's reach so that they had time to familiarize themselves with the mirror and gain confidence, then move on to more challenging sets. The teaching strategy used was Response Prompt with Most to Least Prompt (hand on hand/hand on wrist/hand on forearm/hand on elbow/hand on biceps/hand on shoulder) until children completed the set independently.

Response prompting using a most-to-least prompting hierarchy is a systematic instructional strategy employed within applied behavior analysis (ABA) to teach new skills. This approach involves the delivery of prompts in a graduated sequence, beginning with the most intrusive or controlling prompt (e.g., full physical guidance as the hand-on-hand prompt) and systematically fading to less intrusive prompts (e.g., partial physical guidance as hand on shoulder prompt) as the learner demonstrates increased independence. This procedure is implemented using an errorless learning paradigm to maximize success and minimize prompt dependency (Vascelli et al., 2021).

A training session consisted of ten Learn Units (LU) during each therapy session. We set the mastery criterion at 90% for two consecutive times but on different days, or 100% on one occasion.

We graphically set up a condition change line for each phase of the Most to Least Prompt used for data collection. We initially presented each set to the child in the "hand-on-hand prompt" condition, and a "+" was marked each time the participant performed the Imitation correctly with the help of the therapist; we marked a "-" when the participant did not emit the correct response even after the prompt's presentation. If the event of non-occurrence of the behavior, the experimenter implemented the correction procedure. Once the participant had reached the acquisition criterion in the first condition (hand-on-hand Prompt), one could move on to the following (hand-on-wrist Prompt) and so on until the participant reached the "Independent" condition. The therapist could move on to the next set once the participant acquired the actions in the latter condition.

If a participant could perform the actions without the therapist's help in the Most to Least Prompting, they proceeded directly to the "Independent" condition without fading the Prompt. In this condition, a "+" was marked if the participant performed the Imitation correctly independently and a "–" if they did not perform the expected movement, followed by the correction procedure.

We reported data daily on the charts of each participant. The experiment occurred in the room where ABA therapy usually occurred, containing various types of games (sensory and symbolic play), a bookcase, a large storage cupboard for materials, and four small tables with two chairs each. For safety reasons, the experimenter positioned a mirror against one wall only during the implementation of this procedure. The mirror measured 70x150 cm and was easily transportable from one room to another.

During the training phase, the children sat on a chair in front of the mirror, about one meter away, while the therapists sat slightly to the left so that every movement of both could be visible.

Before making each request, we determined the motivational operation based on the child's preferred reinforcer. We refrained from requesting if the child was not paying attention to the therapist in the mirror.

Experimental design

Due to the inhomogeneous sample and to highlight the Mirror Protocol's results on different functions, the study used a single-subject design with pre- and post-problems for each participant. A multiple-probe design would have ensured comparison baselines to achieve experimental control.

Procedure

The experimental procedure was divided into three phases: the first pre-probe phase, helpful in investigating the presence of Generalized Imitation in the three reference contexts (1:1 with the Imitation of 20 GMI, 1:1 with the Imitation of 15 vocal actions, and during the shared circle time); the second training phase with the implementation of the Mirror Protocol; and the third and final post-Probe phase, to investigate the acquisition of Generalized Imitation following the training.

All phases were carried out by each participant's therapists, thus facilitating compliance and therapy management for the other children at the center.

We conducted the pre-probe phase during an entire therapy session to facilitate motivational operations and keep the children focused on the instructions. The experimenter sat in front of the participant, without a table in between, and asked him to imitate a gross motor action (GMI) or a vocal action. The experimenter presented the instructions using variable antecedents ("Do this," "Do like me," "Do the same") throughout the probe.

During circle time, at least one other child and their therapist needed to be present during the session to create a small group context. They were then all placed in a semicircle with one therapist in front of them and one either to the side or behind to keep the focus on the activity. We decided to have the second child's therapist do the movements to prevent the participant from following the therapist's movements because they were already conditioned to her and not because of an intrinsic motivation to imitate. Once the children focused their attention, music started, and the children were encouraged to mimic the movements shown.

For all three Probes, "+" was put in case of a correct answer and "-" in case of incorrect actions, outside the accepted variants, or no answer. We set The mastery criterion at 90%.

Once the pre-probe phase was over, we moved on to the training phase, in which the Mirror Protocol was implemented like any other program, alternating with the day's activities. After choosing the Set of GMI, the child and the therapist sat in front of the mirror, with the latter proposing LUs with

variable antecedents ("Do this"/"Do as I do"/"Do the same"). A "+" was given for correct answers (with the Prompt in the Most to Least condition and without help in the "Independent" condition), and the children were then reinforced both socially and with favorite games or foods. A "-" was given only when, during the Most to Least Prompting, the child did not allow himself to be guided by the therapist and in the "Independent" condition when he did not carry out the instruction or gave an incorrect answer.

Only after acquiring the set during the "Independent condition" could the participant move on to the next one. We set the acquisition criterion at 90% for two consecutive times, but on different days, or at 100% for one time.

Children could enter the post-probe phase once they had completed all the sets or directly at the end of the agreed training period. The latter phase was carried out similarly to the pre-probe phase.

Data collection and IOA

All study data were collected by trained and competent personnel, as described in the previous paragraphs. Before the research began, we asked all participants' parents to sign informed and data processing consent forms. We computed the Inter-Observer Agreement (IOA) for the six study participants on all probes. The IOA is calculated from the data taken from two independent observers, dividing the number of agreements by the total data in agreement, adding the data in disagreement, and multiplying by 100 (Cooper et al., 2007). An IOA of 95% was considered acceptable. For the probe sessions, the calculated IOA was 97%.

Results

Figures 1, 2, and 3 show the results obtained in the probe phase for the three dependent variables, respectively. The bar graphs show each participant's overall performance in percentages compared to pre- and post-probe conditions.

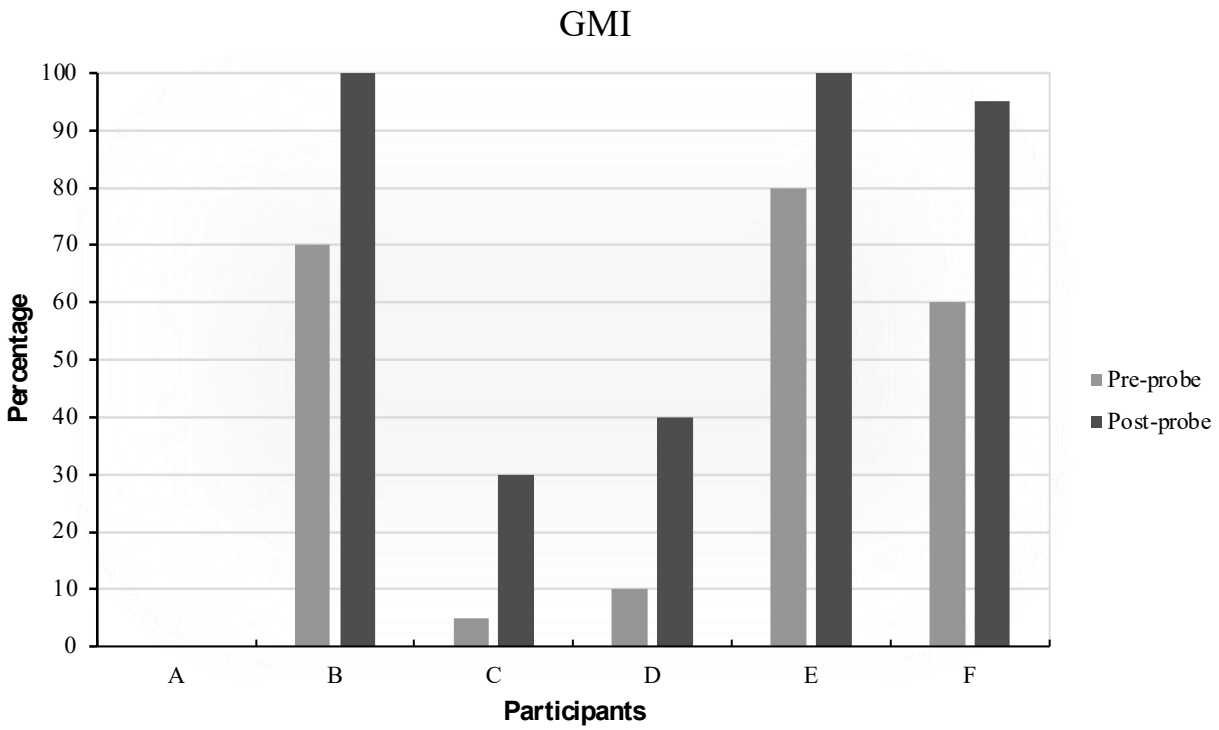

Figure 1. Graph of participants' pre- and post-probe performance in percentage terms on the dependent variable "GMI."

In the condition investigating Generalized Imitation with Gross-Motor Imitation (GMI), all participants except A demonstrated some competence in the pre-intervention phase, but none reached the acquisition criterion. Overall, five participants showed a substantial improvement in GMI imitation at post-probe. However, only B, E, and F, who had shown the best skills at the initial stage (70%, 80%, and 60%), reached the expected acquisition criterion, with 100% and 95% of imitations correct. Participant A showed no imitative skills in either the initial or final phase. These results can be explained by his level of verbal development, as he was the only one to carry out the study in the Pre-Listener phase and had never started ABA therapy before. Given the starting conditions, a training period of only two months cannot have significantly influenced performance.

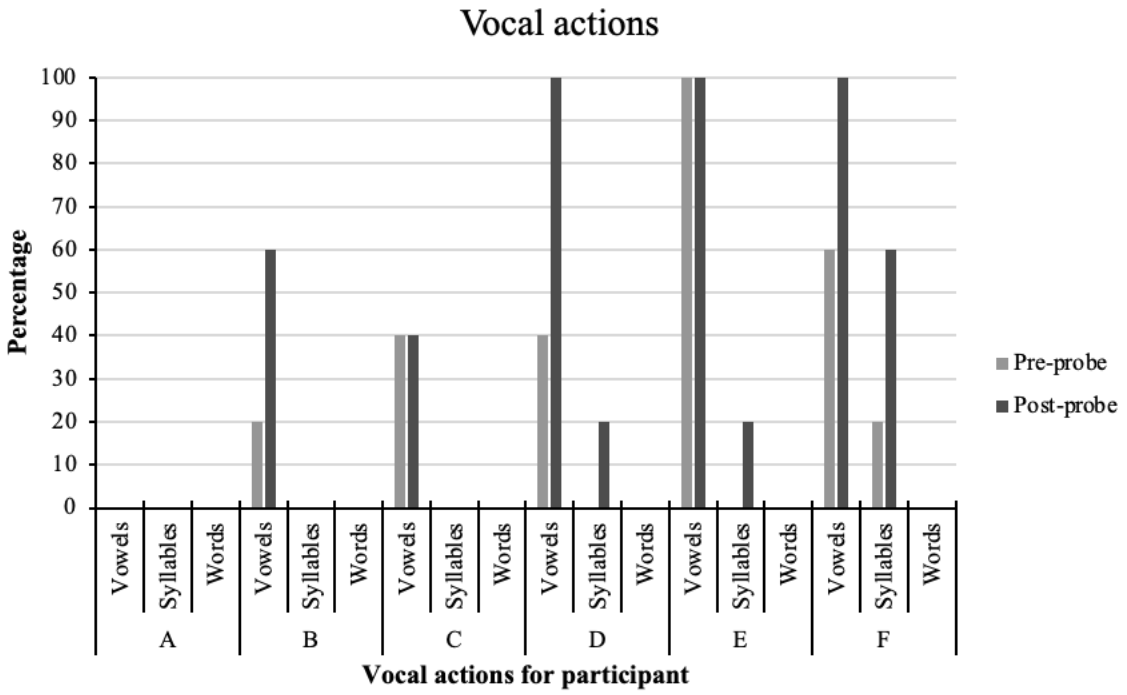

Figure 2. Graph of participants' pre- and post-probe performance in percentage terms on the dependent variable "Vocal actions."

Figure 2 shows the percentage performance of all participants for the second variable investigated, the Imitation of vocal actions. First of all, an increase in the performance of participants B, D, and F in the "vowels" area emerges; participants C and E did not change their scores (40% and 100%, respectively), while participant A did not show this ability neither in the pre-probe nor in the post-probe phase. Participants D, E, and F also improved in the "syllables" area, two of whom developed this as a new skill. No results were obtained for words, presumably because this skill is also susceptible to other variables and is not only related to imitation. The only participants reaching the criterion set for imitating vowel sounds in post-probe were D, E, and F. Although four out of six children improved in skills that were already present and/or developed new areas, the training was too short to observe complete results in a complex skill like language. Despite this, the results obtained are favorable and in line with the literature on the Mirror Protocol, which is supposed to foster the development of Generalized Imitation and, in turn, vocal behaviors (Greer, 2020).

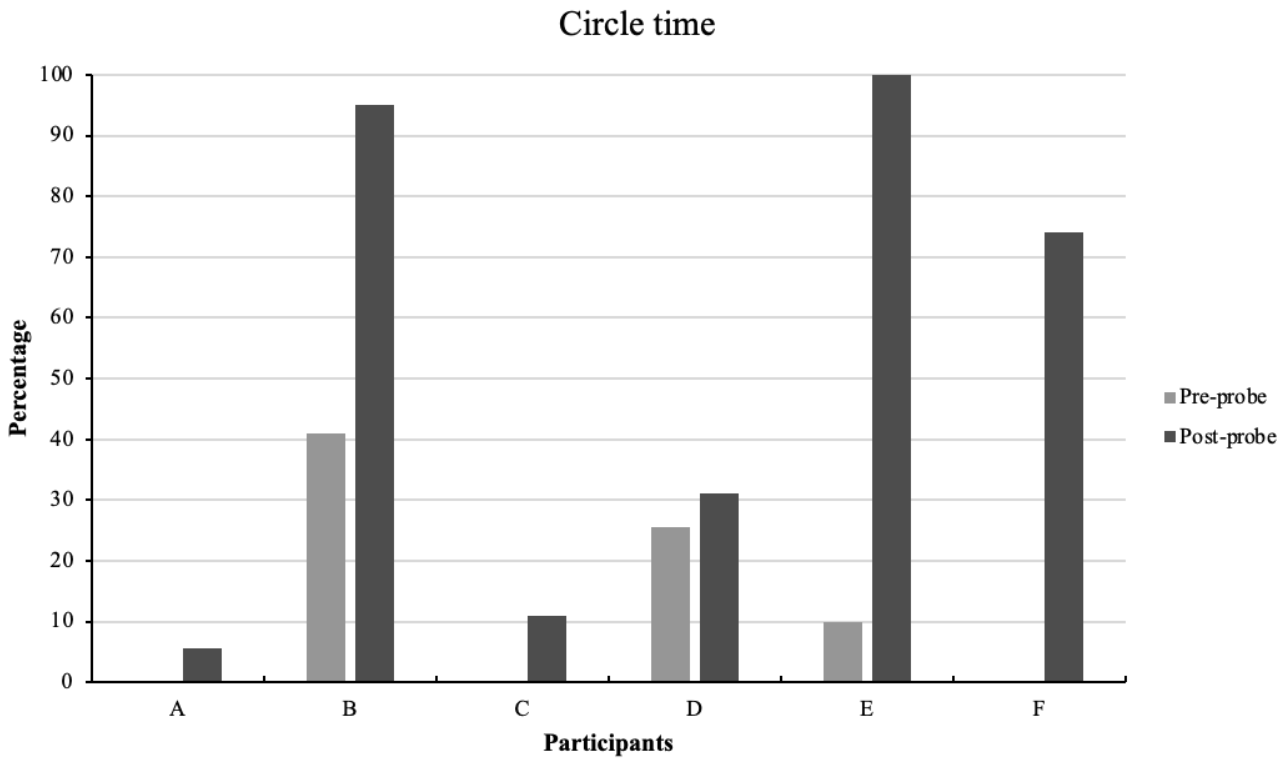

Figure 3. Graph of participants' pre- and post-probe performance in percentage terms on the dependent variable "Circle time."

The last dependent variable investigated was the "Circle Time" condition (Figure 3), in which children had to imitate two simple dances in a group context. In this case, all participants showed improvements, including participant A, albeit with a minimal increase. This result could be related to the interest shown in the pre-probe phase of the songs. Indeed, we could observe eye contact with the therapist dancing only during this rehearsal. Only participants B and E reached the post-probe criterion (95% and 100%), showing a significant improvement. In general, an increased interest in circle time activities was observed following the training phase, showing more motivation to imitate the movements made by adults and peers.

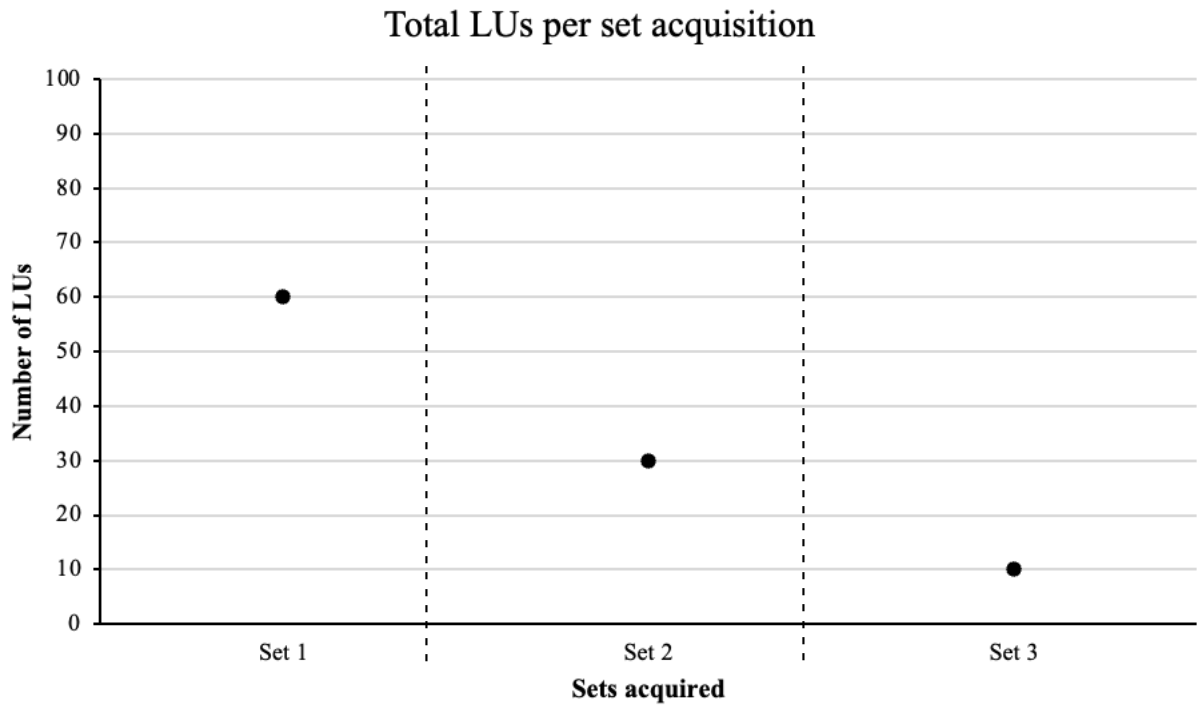

Figure 4. Total number of Learn Units valid for acquiring sets for participant F

Finally, a figure considered beneficial to report was the number of Learn Units required to acquire sets during training. Overall, the sets acquired for each participant were zero for A, eleven for B, one for C, one for D, ten for E, and three for F. Participant B was the only one to have acquired all the expected sets. In contrast, Participant A reached the criterion at one stage, fading the first set of prompts.

We performed a trend analysis for all participants concerning the requests required to reach the criterion in the various sets. The results showed that using the mirror did not accelerate learning and, thus, decreased the LUs needed for acquisition. The number of learning opportunities remained constant for five participants, except for F. As shown in Figure 4, the participants required 60, 30, and 10 requests over three sets to reach the criterion, showing a possible correlation between mirror use and learning acceleration.

This finding is interesting because the purpose of including F within the research was also to investigate how the mirror could increase the accuracy of the correspondence between observed and imitated movements. In fact, due to the participant's motor dyspraxia, his movements had hitherto been inaccurate and fluid. The results shown in Figure 4 align with an improvement in accuracy, another variable that certainly made it possible to speed up the acquisition of the sets.

Discussion

Although the participants met a few criteria in each condition, we could observe overall improvements in their performance, although not homogeneously, for all three dependent variables. On a statistical level, the analysis did not confirm the acquisition of generalized imitation for any participant. Using the Mirror Protocol alone in teaching GMI brought rapid improvements in skills not directly taught during the two months of training. These findings contribute to the literature that supports the claim that the mirror can act as a facilitator for the learning and generalization of imitative skills (Pereira Delgado, Speckman, & Greer, 2009; Du, 2011; Moreno, 2012; Du & Greer, 2014; Miller et al., 2015; Wilczewski, 2022; Scattolin et al., 2021).

Furthermore, the results of the study confirm how the use of the Mirror Protocol can stimulate the emergence of vocal actions (Poon et al., 2012; Scattolin et al., 2021; Wilczewski, 2022). Language is a complex skill that relies on other prerequisites besides imitation, which is why, in the present study, children showed improvements only in vowel imitation and simple syllables but not in words. The encouraging result is that most participants did not have syllabic imitation in their repertoire and that some developed this skill in just two months of the Mirror Protocol training.

From a qualitative point of view, in language, significant results were achieved by participants B and F, both non-vocalic. Although the former only improved his vowel imitation competence, he showed in post-probes excellent imitative abilities of the oral motors performed by the therapist to pronounce syllables and words, although not followed by any sound. For Participant F, on the other hand, although the ability to imitate the words used in the probe did not emerge, following the training, he began spontaneously and for the first time to pronounce the words "mom" and dad."

Concerning the trend on the participants' learning speed, it remained constant for all children except for F. This result is not in line with the literature, according to which the use of the mirror should facilitate and speed up learning, reducing the teaching opportunities required to acquire a skill (Miller et al., 2015). The result obtained by Participant F, however, opens the door to a possible research question on the use of the mirror as a learning facilitator in cases of motor dyspraxia, allowing the child to contact the correspondence between the movements directly observed and those reproduced by him (Pereira Delgado, Speckman, & Greer, 2009). For this child, the mirror helped him correct himself independently or with the therapist's help, consolidating topographically accurate movements, which were maintained over time (Miller et al., 2015).

The result obtained by F allows the connection with another qualitative consideration that is considered beneficial to the report. In participants B, D, E, and F, we observed a considerable improvement in compliance following the use of the mirror, to the extent that the children themselves

requested it during the activities. In line with the literature, participants showed great attention to the mirror and self-correcting abilities towards the movements produced, increasingly seeking a perfect correspondence of action. These results were obtained thanks to the intrinsic reinforcement by observing the correspondence between their movements and those of the therapists in the mirror, which increased the motivation to perform the activity (Greer & Speckman, 2009).

Furthermore, sustained attention, trained with the Mirror Protocol, allowed participants to spontaneously turn their attention to other stimuli previously considered unmotivating, such as circle time. The training increased sustained attention and Generalized Imitation, enabling all participants to improve their post-probe performance and broaden their range of interests with a highly socializing activity.

Participant C was the only one not intrinsically motivated by using the mirror. In line with Avelar's (2017) study, she only enacted the problem behavior (complaining while simulating crying) in front of the mirror, as she was reinforced by observing herself. The instrument thus proved to be a distractor rather than a facilitator of learning. The participant was more compliant with the demands at the desk than in the training phase.

Limits and future perspective

The study's main limitations are the non-homogeneity of the participants' verbal development level and the small sample size. These variables led to using a single-subject experimental design instead of an experimental and control group design, in which the sample is homogeneous in terms of age and level of development. Given the single-subject design and the exploratory aims of the study, inferential statistical indicators were not calculated. However, raw data (percentages, Lus, follow-up trends) have been provided to ensure transparency. Future studies could involve a larger number of participants and include inferential statistical analyses to enhance the generalizability of the findings.

Time was another significant limitation of the study. Two months of training proved insufficient for children such as Participant A, who is classifiable as a pre-listener and not used to ABA therapy, or Participant C, who is not compliant with any demands. In addition, the dependent variable of Imitation of vocal actions is so complex that it requires more time to emerge.

Another limitation concerns the linguistic background of some participants, who were not native Italian speakers. Although we designed the tasks to be mainly visual and motor-based, it is possible that language comprehension, particularly in the vocal imitation trials, may have influenced the performance of some children. Future studies should more systematically consider the role of language competence in imitation teaching protocols. Future research is needed to explore how the effectiveness of Mirror Protocol interventions may vary across different age groups and autism

severity levels. It is hypothesized that school-age children may exhibit slower progress and less stable maintenance of imitative skills, given that foundational competencies such as generalized imitation are expected to have developed earlier. Moreover, the presence or absence of triadic attention appears to be a critical factor influencing treatment efficacy, particularly in children with more severe autism. A lack of this ability may hinder the child's capacity to attend to mirrored actions, compromising both engagement and learning.

Finally, it would be of considerable interest to investigate the adaptability of the Mirror Protocol for children with other neurodevelopmental disorders, potentially broadening its scope of application and informing transdiagnostic intervention strategies.

Conclusion

Although it is impossible to affirm the acquisition of Generalized Imitation in any of the participants, their direction is excellent, with all trends ascending. Considering the results obtained by each child, it is possible to observe the effectiveness of the Mirror Protocol in increasing imitative ability in most conditions, favoring and increasingly encouraging the acquisition of generalized Imitation.

Acknowledgments, Grants, and Funding

This research received no specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of Interest statement

Declarations of interest: none.

Authors' contribution

Author 1 assisted with concept, study design, data analysis, manuscript preparation, and manuscript editing; Author 2 assisted with manuscript editing, data analysis, data interpretation, and study supervision; Author 3 assisted with manuscript editing and study concept; Author 4 assisted with the generation of the initial draft of the whole manuscript, manuscript editing and data interpretation; All authors contributed to and have approved the final manuscript.

References

American Psychiatric Association (2013). *Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition, DSM-5.* Raffaello Cortina Editore, Milan, 2014.

Avelar, G. (2017). *Teaching Imitation to Children with Autism Using Most-to-Least Prompt Fading in Front of a Mirror*. Western Michigan University.

Baer, D., Peterson, R., & Sherman, J. (1967). The development of Imitation by reinforcing behavioral similarity to a model. *Journal of the Experimental Analysis of Behavior, 10*(5), 405–416. https://doi.org/10.1901/jeab.1967.10-405

Caldwell, N. S. (2020). *A pilot randomized controlled trial of imitation intervention on generalized imitation in young children with Autism Spectrum Disorder* [Doctoral dissertation] University of Texas at Austin.

Carpenter, M. (2006). Instrumental, social, and shared goals and intentions in Imitation. In S. J. Rogers & J. Williams (Eds.) *Imitation and the social mind: Autism and typical development* (pp. 48–70). New York: Guilford Press.

Carpenter, M., Akhtar, N., & Tomasello, M. (1998). Fourteen-through 18- month-old infants differentially imitate intentional and accidental actions. *Infants Behavior & Development, 2,* 315–330. https://doi.org/10.1016/S0163-6383(98)90009-1

Catania, A. C. (2007). *Learning (4th ed.).* New York: Sloan Publishing.

Catania, A.C. (2007). *Learning (5th ed*.). Cornwall-on-Hudson, NY: Sloan Publishing.

Du, L. (2011). *The Effects of Mirror Instruction on the Emergence of Generalized Imitation of Physical Movements in 3-4 Years Olds with Autism* [Doctoral dissertation]. Columbia University.

Du, L., & Greer, R. D. (2014). Validation of adult generalized imitation topographies and the emergence of generalized Imitation in young children with autism as a function of mirror training. *The Psychological Record*, *64*, 161-177. https://doi.org/10.1007/s40732-014-0016-2

Edwards, L. A. (2014). A meta-analysis of imitation abilities in individuals with autism spectrum disorders. *Autism Research, 7,* 363–380. https://doi.org/10.1002/aur.1360

Fiese, B. H. (1990). Playful relationships: A contextual analysis of mother-toddler interaction and symbolic play. *Child Development, 61,* 1648–1656. https://doi.org/10.2307/1130876

Greer, R. D. (2002). *Designing teaching strategies: An applied behavior analysis systems approach.* San Diego, CA: Academic Press.

Greer, R. D. (2020). The selector in behavior selection. *The Psychological Record, 3,* 1–1. https://doi.org/10.1007/s40732-020-00408-6

Greer, R.D. & Speckman, J.M. (2009). Integrating speaker and observing responses: Joining the speaker and Listener within the skin. *Psychological Record, 59,* 449–488. https://doi.org/10.1007/BF03395618

Greer, R.D., & Ross, D.E. (2008). *Verbal behavior analysis: inducing and expanding new verbal capabilities in children with language delays.* Boston, MA: Allyn & Bacon.

Jones, S. S. (2007). Imitation in infancy: The development of mimicry. *Psychological Science, 18,* 593–599. https://doi.org/10.1111/j.1467-9280.2007.01946.x

Keohane, D., Pereira Delgado, J., & Greer, R.D. (2008). *Observing responses as the foundation for complex verbal behavior. Derived relational responding: Applications for Learners with autism and other developmental disabilities.* Oakland, CA: New Harbinger Publications.

Lovaas, O. I., Freitas, L., Nelson, K., & Whalen, C. (1967). The establishment of Imitation and its use for the development of complex behavior in schizophrenic children. *Behavior Research and Therapy, 5*(3), 171-181. https://doi.org/10.1016/0005-7967(67)90015-0

Meltzoff, A. N. (2007). "Like me": A foundation for social cognition. *Developmental Science, 10,* 126-134. https://doi.org/10.1111/j.1467-7687.2007.00574.x

Metz, R. J. (1965). Conditioning generalized Imitation in autistic children. *Journal of Experimental Child Psychology, 2*(4), 389–399. https://doi.org/10.1016/0022-0965(65)90042-7

Miller, S. A., Rodriguez, N. M., & Rourke, A. J. (2015). Do mirrors facilitate the acquisition of motor imitation in children diagnosed with autism? *Journal of Applied Behavior Analysis*, *48*(1), 194–198. https://doi.org/10.1002/jaba.134

Moreno, J. D. (2012). *Imitation instruction using a mirror affects the emergence of duplicative responses by preschool students diagnosed with developmental delays* [Doctoral dissertation]. Columbia University.

Pereira Delgado, J. A. Speckman, J., & Greer, R. D. (2009). The emergence of generalized Imitation in two—to four-year-olds with developmental delays as a function of teaching Imitation in a mirror. In J. Dudek (chair), *From Learning to Observe Through Learning From Observation.* The symposium was conducted at Cobham, UK's Comprehensive Application of Behavior Analysis 3rd International Conference.

Piaget, J. (1951). *Play, dreams, and Imitation in childhood*. London, England: Routledge and Kegan Paul, Ltd.

Poon, K. K., Watson, L. R., Baranek, G. T., & Poe, M. D. (2012). To what extent do joint attention, Imitation, and object play behaviors in infancy predict later communication and intellectual functioning in ASD? *Journal of Autism and Developmental Disorders, 42,* 1064–1074. https://doi.org/10.1007/s10803-011-1339-5

Rizzolatti, G. (2005). The mirror neuron system and Imitation. In S. Hurley & N. Chater (Eds.), *Perspectives on Imitation, Volume 1: From neuroscience to social science—Mechanisms of Imitation and Imitation in animals* (pp. 55–76). Cambridge, MA: MIT Press.

Ross, D. E., & Greer, R. D. (2003). Generalized Imitation and the mand: Inducing first instances of speech in young children with autism. *Developmental Disabilities, 24,* 58-74.

Scattolin, A., Artoni, V., Giannatiempo, S., Martino, F., & Berardo, F. (2021). "Mirror Protocol" for teaching Generalized Imitation to a child with intellectual disability. *Autism and Neurodevelopmental Disorders*, (17), N-A.

Schreibman, L., Dawson, G., Stahmer, A., Landa, R., Rogers, S., McGee, G., ... Halladay, A. (2015). Naturalistic Developmental Behavioral Interventions: Empirically Validated Treatments for Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders, 45*(8), 2411–2428. https://doi.org/10.1007/s10803- 015-2407-8

Skinner, B.F. (1953). *Science and human behavior.* New York: Macmillan.

Tsiouri, I., & Greer, R. D. (2003). Inducing vocal verbal behavior through rapid motor imitation training in young children with language delays. *Journal of Behavioral Education, 12*, 185–206. https://doi.org/10.1023/A:1023619220298

Tsiouri, I., & Greer, R. D. (2007). Different social reinforcement contingencies in inducing choices to tacts through motor imitation responding in children with severe language delays. *Journal of Early and Intensive Behavioral Interventions, 3,* 629–647. https://doi.org/10.1037/h0100414

Uzgiris, I. C. (1990). The social context of infant imitation. In: M Lewis, & S. Feinman (Eds.) *Social influences and socialization in infancy* (pp. 215-251). New York: Plenum Press.

Vascelli, L., Iacomini, S., Artoni, V., & Cihon, T. M. (2021). Teaching self-care and domestic living skills using least-to-most prompting procedure in a semi-residential setting. *Journal of Clinical & Developmental Psychology*, *3*(2).

Vassare, B. M. (2017). *The effects of peer monitoring on observational stimulus control in preschoolers with and without social delays; In-vivo versus learning versus performance* [Doctoral dissertation]. Available from ProQuest Dissertations and Theses database. (UMI No. 10275090).

Wilczewski, J. (2022). *Establishment of the Imitation Developmental Cusp via a Synchronous Mirror Protocol and the Role of Imitation as a Foundational Verbal Cusp* [Doctoral dissertation]. Columbia University.

APPENDICES

Table 1. *Gross-motor stock probes (GMIs)*

GMI	Description	Accepted Variations	+/-
1. Point to the neck	Right-hand index finger points to neck	Tap the neck	
2. Join hands	Join hands as if in prayer	Hands together	
3. Tap your shoulders	Fingers press on the shoulders	Touch shoulders with hands	
4. Touch the ground	Touch the floor with the palm of your right hand	Touch the floor	
5. Salta	Jump with your feet together	Salta	
6. Point to the head	Right-hand index finger touch head	Touch head to hand	
7. Bale	Rotate the trunk and move bent arms back and forth	Move arms bent back and forth	
8. Point to your knees	Right-hand index finger points to knee right leg	Knee Touch	
9. Raise your thumb	Closed hand with right thumb raised	Hand closed, thumb up	
10. Scratch the head	The fingers of the right hand scratch the head	He moves his hand over his head	
11. Raise your feet	Lift your feet off the ground	Lift at least one foot off the ground	
12. Rub your mouth	Move your right palm resting on your mouth from left to right and vice versa.	Touch mouth	
13. Move your head up and down.	Move head from top to bottom.	Moves his head	
14. Touch the forehead	Touch with fingers of the right-hand forehead	Touch Front	
15. Clap your shoulders	Double-tap your palms on both shoulders	Tap your shoulders	

16. Stand up	Switches from sitting to standing and maintains position	Switch between sitting and standing
17. Finger to finger	Tap the index finger of the left hand with the index finger of the right hand.	Fingers hands touch
18. Move your arms up and down.	Both hands move up and down alternately	Both arms move up and down
19. Touch the cheek with a finger.	The index finger of the right-hand touches the cheek	Touch cheek
20. Hands that simulate "driving."	Fisted hands that go up and down alternately	Hands moving up and down

Table 2. *Voice Action Probe*

		+/-				
		1	**2**	**3**	**4**	**5**
(a) Vowel sounds (prolonged: AAA..)	**A-E-I-O-U**					
(b) Simple syllabic sounds	**MA-CA-PE-LU-SO**					
(c) Simple words	**MOUSE-ONE-HOUSE-APPLE-STREET**					

Table 3. *Ballet probe for the song "There are two crocodiles"*

There are two crocodiles (9 LUs tot)	**Description**	**Accepted Variations**	**+/-**
Crocodile Makes (1LU)	Arms forward on top of each other and clap hands	Claps hands	
Fa la orangutano (1LU)	Alternate chest punches	Punches on the chest	
Snake Makes (1LU)	Waves with arms forward	Arms forward	
Fa L'Aquila (1LU)	She opens her arms and sways up and down	Opens arms	
Fa il Gatto (1LU)	Straight hands resting on the head	Hands-on head	
Makes the mouse (1LU)	Fingers tracing the mustache	Fingers above the mouth	
Elephant Maker (1LU)	An arm outstretched forward, waving	Forward arm	
Search gesture (1LU)	Visor hand over the eyes	Hand over eyes	
Fa i leocorni (1LU)	Index fingers stretched above the forehead	Fingers on the head	

Table 4. *Ballet probe for the song "La zia di Forlì"*

I have an aunt who does this (10 LUs tot)	**Description**	**Accepted Variations**	**+/-**
Raise your hands high (1 LU)	Bring your hands up vertically	Hand holder up vertically	

Foot Stamp (1 LU)	Moves feet up and down alternately	Moves feet up and down
Hip Moves (1 LU)	Moves flanks to the right and left	Moves hips
Touch Head (1 LU)	Touch your head with your palms	Touch the head
Touch knees (1 LU)	Touch your palms to your knees	Touch your knees