Research in Developmental Disabilities 83 (2018) 287–295

Contents lists available at ScienceDirect

Research in Developmental Disabilities

Persistent primary reflexes affect motor acts: Potential implications for autism spectrum disorder

Alice Chinello[a], Valentina Di Gangi[b], Eloisa Valenza[b,*]

[a] *Physiotherapist at ULSS 16 – Unità Locale Socio Sanitaria, Padova, Italy*
[b] *Department of Developmental Psychology and Socialization, University of Padua, Italy*

ARTICLE INFO

Article history:
Received 11 October 2015
Received in revised form 19 July 2016
Accepted 22 July 2016
Available online 29 August 2016

Keywords:
Primitive reflexes
Motor acts
Communicative gestures
Broader Autism Phenotype

ABSTRACT

In typical motor development progress in use of goal-directed actions and communicative gestures depends on the inhibition of several primitive reflexes, especially those that involve the hand or mouth. This study explored the relationship between the persistence of primitive reflexes that involve the hand or mouth and the motor repertoire in a sample of 12- to 17-month-old infants. Moreover, since children with Autism Spectrum Disorders (ASD) often have difficulty in performing skilled movements and show poor gesture repertoire, and since ASD represents the upper extreme of a constellation of traits that may be continuously distributed in the general population, we investigated the relationship between the persistence of primitive reflexes in the same sample of infants and the subclinical autistic traits measured in their parents. Results revealed that the persistence of the primitive reflexes correlated with motor repertoire irrespective of infant's age, and it was greater among infants whose parents had more subclinical autistic traits. Our findings suggest that the persistence of primitive reflexes might alter the developmental trajectory of future motor ability and therefore their evaluation might be an early indicator of atypical development.

© 2016 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

1. Introduction

Currently researchers are increasingly recognizing the effect that motor skills have on other areas of development, such as social cognition and language (Leonard & Hill, 2014). The emergence of new motor skills changes infants' experience with objects and people in ways that are relevant for both general communicative development and the acquisition of language (Iverson, 2010). For instance, it was found that motor skills at 18 months were good predictors of communication skills at 3 years, supporting the hypothesis that early variance in motor abilities is useful in understanding later development of language and communication (Wang, Lekhal, Aarø, & Schjolberg, 2012).

In addition to the primary diagnostic criteria for Autism spectrum disorder (ASD) reported in the Diagnostic and Statistical Manual of Mental Disorders (DSM-5, 5th edition, American Psychiatric Association, 2013), children with autism often have difficulty in performing skilled movements and show poor gesture repertoire (Gernsbacher, Sauer, Geye, Schweigert, & Goldsmith, 2008; McDuffie et al., 2007; Ozonoff et al., 2008; Stone, Ousley, Yoder, Hogan, & Hepburn, 1997; Watson, Crais, Baranek, Dykstra, & Wilson, 2013). Using retrospective reports of manual motor skills in children with an ASD diagnosis,

* Corresponding author at: Dipartimento di Psicologia dello Sviluppo e della Socializzazione, Università degli Studi di Padova, via Venezia 8, 35131 Padova, Italy.
E-mail address: eloisa.valenza@unipd.it (E. Valenza).

https://doi.org/10.1016/j.ridd.2016.07.010
0891-4222/© 2016 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Gernsbacher and colleagues (2008) found that children classified as having highly fluent speech in an assessment by a speech-language professional were reported to have much better manual motor skills in early life than those with moderately fluent or minimally fluent speech. Reports of the early manual motor skills of a proportion of the children were corroborated by home video analysis by researchers blind to the results of the caregiver interview.

Moreover, a growing body of evidence suggests that adults and children with ASD show abnormalities of postural control (Fournier, Hass, Naik, Lodha, & Cauraugh, 2010; Bhat, Landa, & Galloway, 2011; Schmitz, Martineau, Barthélémy, & Assaiante, 2003). For example, studies using force platform technology to measure postural sway have consistently reported that individuals with ASD exhibit greater postural sway during quiet stance than typically developing individuals.

Based on these findings, it has been suggested that motor delays during the first years of life predict the main impairments that are characteristic of ASD (Bhat et al., 2011; Kaur, Srinivasan, & Bhat, 2015). This hypothesis has been tested in infant siblings of children diagnosed with ASD, who have a heightened risk of developing ASD. A longitudinal study of motor development in 3- to 6-month-old high risk (HR) infants (Bhat, Galloway, & Landa, 2012) reported that 70% of HR infants with early motor delays subsequently exhibited communication delays.

Similarly, LeBarton and Iverson (2013) reported that fine motor skills in 12-month-old HR infants predicted expressive language at 36 months. During free exploration of objects HR infants show reduced mouthing and grasping, and at six and nine months old HR infant also show excessive looking (Iverson, Capirci, & Caselli, 1994; Iverson & Fagan, 2004; Iverson & Thelen 1999; Koterba, Leezenbaum, & Iverson, 2014). These findings were supported by a recent longitudinal study of different forms of object exploration (including oral, visual and manual behaviours) in infants exploring three objects of varying size. The data revealed object-based differences in exploration patterns between HR and low risk (LR) infants (Libertus & Landa, 2014). Together, these findings suggest that infants at HR for ASD show atypical motor development patterns that seem to predict social and linguistic outcomes. Studies of postural control also suggest that a pattern of postural delays and abnormalities emerges relatively early - well before the end of the first year - in infants who will later receive a diagnosis of ASD (Esposito, Venuti, Maestro, & Muratori, 2009; Nickel, Thatcher, Keller, Wozniak, & Iverson, 2013; Ozonoff et al., 2008; Teitelbaum, Teitelbaum, Nye, Fryman, & Maurer, 1998).

It was suggested that almost all of the movement disturbances in autism can be interpreted as infantile reflexes "gone astray"; i.e., some reflexes are not inhibited at the appropriate age in development, whereas others fail to appear when they should (Teitelbaum et al., 2004).

Indeed, progress in motor development is related to a reflexive process, in which the infant gradually matures by the inhibition of more primitive motor forms (Teitelbaum et al., 2004).

Primary (or primitive) reflexes are muscle reactions that occur automatically in response to a specific stimulus; they emerge during foetal development and are critical for the survival of the newborn infant (Castiello et al., 2010; Zoia et al., 2007). Primary reflexes are readily elicited during the first six months after birth (Allen & Capute, 1989; Capute et al., 1984; Dubowitz, Dubowitz, & Mercuri, 1999; Jordan-Black, 2005; Khan, Garcia-Sosa, Hageman, Msall, & Kelley, 2014; McPhillips & Jordan-Black, 2007; Yang, 2004; Zafeiriou, 2004), however, as the nervous system matures, they are progressively inhibited and gradually superseded by postural reflexes (Fong, Tsang, & Ng, 2012; Geuze, 2003; Wilkinson, 1994).

If primary reflexes are retained beyond the normal developmental period they have the potential to disrupt maturation processes and reduce the brain's ability to process sensory information effectively (Goddard Blythe, 2000, 2011; Parfrey, Gibbons, Drinkwater, & Behm, 2014). In other words, the persistence of primary reflexes beyond the normal timespan (12 months) interferes with subsequent development and is indicative of neurological impairment (Holt, 1994).

Severe persistence of primary reflexes predominantly indicates intractable physical problems such as cerebral palsy (Pavão, Neves dos Santos, Woollacott, & Cicuto Ferreira Rocha, 2013), whereas milder persistence is associated with less severe disorders including learning difficulties (McPhillips, Hepper, & Mulher, 2000; McPhillips & Jordan-Black, 2007; McPhillips & Sheehy, 2004). In summary, the inhibition of primitive reflexes enables the development of motor skills that allow the infant to act on and interact with the environment in increasingly complex ways.

In light of the relatively rapid pace at which typically developing infants become capable of goal-directed actions and communicative acts (they usually achieve both during the first 18 months of life) it is surprising that no studies have investigated the effects of the persistence of primitive reflexes on motor acts and communicative gestures in infancy. This study attempted to address this gap by exploring the relationship between the persistence of primitive reflexes that involve the hand or mouth and the motor repertoire in a sample of 12- to 17-month-old infants drawn from the general population. We tested three primary reflexes—grasping[1], rooting[2] and sucking[3]. We expected to find a higher rate of persistence of these primitive reflexes in younger than in older infants. We also expected that the persistence of the primitive reflexes would reduce infants' performance in tests of interactions with objects (i.e., actions) and with people (i.e., communicative gestures) irrespective of their age.

[1] The palmar grasp reflex is elicited inserting the index finger into the palm of the infant from the ulnar side and applying a light pressure to the palm. The response of the reflex comprises flexion of all fingers around the finger.

[2] The rooting reflex is elicited stroking with a finger the infant's cheek or mouth. Infant turns the head by moving it in steady decreasing arcs until the finger is found. After becoming used to responding in this way, the infant will move directly to the finger without searching.

[3] The sucking reflex often follows the rooting reflex given that infants instinctively suck anything that touches the roof of their mouth.

We were also interested in investigating, in the same general population-based sample, the relationship between the persistence of primitive reflexes and the subclinical autistic traits measured in their parents who completed a paper version of the Autism Spectrum Quotient questionnaire (AQ; Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001). It is well known that ASD represents the upper extreme of a nexus of traits that are continuously distributed in the general population (e.g., Baron-Cohen et al., 2001; Constantino & Todd, 2003; Dawson et al., 2002). People with a diagnosis of autism manifest autistic traits at the extreme end of this distribution, whereas unaffected family members of autistic individuals may display subclinical autistic-like traits. Therefore, neurocognitive dysfunctions associated with autism can be found not only in affected individuals but also in their genetic relatives, many of whom have social and communication impairments similar to those in ASD, but in milder form (e.g., Baron-Cohen, 1995; Belmonte, Gomot, & Baron-Cohen, 2010; Dawson et al., 2005; Sucksmith, Roth, & Hoekstra, 2011). Bolton and colleagues were the first that referred to the occurrence of these characteristics as evidence of a *broader autism phenotype* (BAP—Bolton et al., 1994). The AQ is a sensitive measure of autistic traits in the general population, implying that traits reaching a clinical level in autism also exist to a lesser degree in nonclinical counterparts (Baron-Cohen et al., 2001; Ruzich et al., 2015). Previous studies have also confirmed a consistent gender difference in the mean AQ score: typical males score significantly higher than typical females, while people of both sexes with an autism spectrum condition score at the extreme high end of the scale, in line with the *extreme male brain* (EMB) theory of autism (Baron-Cohen, 2002; Baron-Cohen et al., 2014). The *extreme male brain theory* posits that there are typical male and female cognitive profiles (‘brain types’) in the general population, in two domains: empathizing (the drive and ability to identify a person’s thoughts and feelings, and to respond to these with an appropriate emotion) and systemizing (the drive and ability to analyze or build systems). Typical females, on average, exhibit more empathizing and less systemizing compared to typical males, and people with autism show an extreme of this ‘male profile’.

We expected that infants whose parents displayed higher levels of autistic traits (although still below the clinical threshold) would also show more persistent primitive reflexes. Moreover, given that, in the nonclinical population subclinical autistic traits are more common in males (Baron-Cohen, 2003; Baron-Cohen et al., 2001; Constantino & Todd 2003; Ruzich et al., 2015), we expected to observe more ASD subclinical traits in fathers than in mothers, and therefore that infant reflex score were mainly related to paternal AQ score.

2. Method

2.1. Participants

The research involved 34 infants (15 boys and 19 girls) aged from 12 to 17 months (average age: 461 days) who were recruited from a list of families who had expressed interest in taking part in infant development studies. All infants were from full-term, uncomplicated pregnancies and were free of known or suspected abnormalities; they were all from middle-class families. Most of the participants (22) were tested in nurseries in a city in northern Italy; the remaining 12 infants were tested in their homes. Fifty-six parents out of the 68 completed the AQ questionnaire. The research protocol was approved by the Padova University ethics committee (protocol n. 1645) and the study was conducted in accordance with the principles of the Declaration of Helsinki. Parents gave written informed consent for their infants’ participation prior to the start of data collection.

2.2. Materials

The persistence of grasping, rooting and sucking reflexes was assessed using Goddard’s scale (Goddard Blythe, 2002). A soft, disposable brush was used to stimulate the hands and mouth of each infant. To elicit the grasping reflex the brush was moved from the radial to the ulnar side of the metacarpal head and from the metacarpal head of the forefinger to the twist of the crease on the radial side. The brush was moved downwards from the outer base of the nose to beyond the corner of the mouth to elicit the rooting reflex, and moved around in the central area above the upper lip to elicit the sucking reflex. All reflexes were assessed using a five-point scale with higher scores indicating greater inhibition of the reflexes.

Actions and communicative gestures were evaluated using a three-point scale, with higher scores indicating better performance. Table 1 reports some examples of actions and communicative gestures proposed to the infants.

Finally, both parents of all infant participants completed a printed version of the five subscales of the AQ questionnaire (social skills; attention switching; attention to detail; communication; imagination) (Baron-Cohen et al., 2001). Higher AQ scores indicate higher levels of autistic traits (the scale measures traits above and below the clinical threshold).

2.3. Procedure

Infants were observed for approximately 25–30 min during a semi-structured play session.

In the first phase infants played freely; this phase was designed to familiarize them with the two researchers (a second observer assessed infants’ behavior; we thus obtained two independent assessments). The observation phase began as soon as the infant appeared to be comfortable with the two researches and available to play with them. During this phase the infant was seated on the floor in front of one of the two researchers. This researcher presented the infant with some toys and invited the infant to imitate her actions (see Table 1). To engage the infants’ attention the actions were introduced as

Table 1
Examples of actions assessed during the observational motor action assessment session.

Action	Play session	Score 1	Score 2	Score 3
Voluntary exhalation	The researcher lights a candle and then blows it out with a strong exhalation. The researcher relights the candle and asks the infant to blow as strong as the wind to blow it out.	The infant does not protrude his/her lips.	The infant protrudes his/her lips without sufficient strength to blow out the candle	The infant protrudes his/her lips efficiently and blows out the candle.
	The researcher inserts a coin into the tray of a cash register. She then presses a button to display the coin in the tray. Finally, she invites the infant to press the button in order to see the coin again.	The infant is not able to press the button or uses the palm of his/her hand to do so.	The infant presses the button using more than one finger.	The infant presses the button using only his/her forefinger.
Disappearing gesture	The researcher inserts a coin into a money box, then opens her hands with the palms facing upwards and says *"the money's not anymore!"* The researcher then inserts another coin and asks to the child *"where is the coin?"*	The infant does not imitate the disappearing gesture, his/her hand are closed	The infant opens the hand but his/her fingers are bent and half-closed	The infant opens the hand, his/her fingers are well extended

behaviors performed by the protagonist in a story. The researcher demonstrated the motor acts several times (maximum of five times). Reflexes were evaluated at the end of the observation phase.

2.4. Variables and coding

The variables analysed included: (1) total score on reflex assessments, (2) total score on the motor assessment and (3) quantitative measure of parental autistic traits (evaluated using the AQ questionnaire). Two independent observers coded all instances of reflexes and actions. The inter-rater agreement was calculated using two indices: simple correlation between the scores given by the two coders ($r = 0.976$; $p < 0.001$; 408 observations) and Cohen's Kappa ($k = 0.883$); both indicated excellent inter-rater agreement.

3. Results and discussion

3.1. Preliminary analyses

The average scores for the assessment of infants' reflexes and motor acts were respectively 20.59 (SD = 5.10) and 27.41 (SD = 4.68).

The effect of age on the presence of primitive reflexes was evaluated as part of the preliminary statistical analyses. Infant age (expressed in days) and primitive reflex score were correlated ($r = 0.394$; $p = 0.021$), confirming that primitive reflexes decrease with increasing age (Fig. 1).

The age effect suggested by the correlation was confirmed by a *t*-test. Participants were divided into two different age ranges: younger than 15 months (n = 16, M age = 14 months, SD = 35 days) and older than 15 months (n = 18, M age = 17 months, SD = 28 days). The *t*-test revealed that primitive reflex score differed between the two age groups ($t_{(19.3)} = -2.644$, $p = 0.016$), indicating that older participants (M = 22.66, SD = 2.52) showed greater inhibition of primitive reflexes than younger participants (M = 18.25, SD = 6.24).

This preliminary analysis confirmed that primitive reflexes decrease with increasing age. This finding is consistent with a maturational account of the inhibition primitive reflexes. Interestingly, the results revealed the presence of primitive reflexes in infants older than 15 months, which is later than the expected date of reflex inhibition (12 months). Further analyses to determine whether the persistence of primary reflexes affected motor performance irrespective infant age were therefore warranted.

Other variables, such as the setting in which the assessment took place (i.e., nursery or home) and participants' gestational age at the time of birth did not influence the dependent variable and were therefore excluded from subsequent statistical analyses.

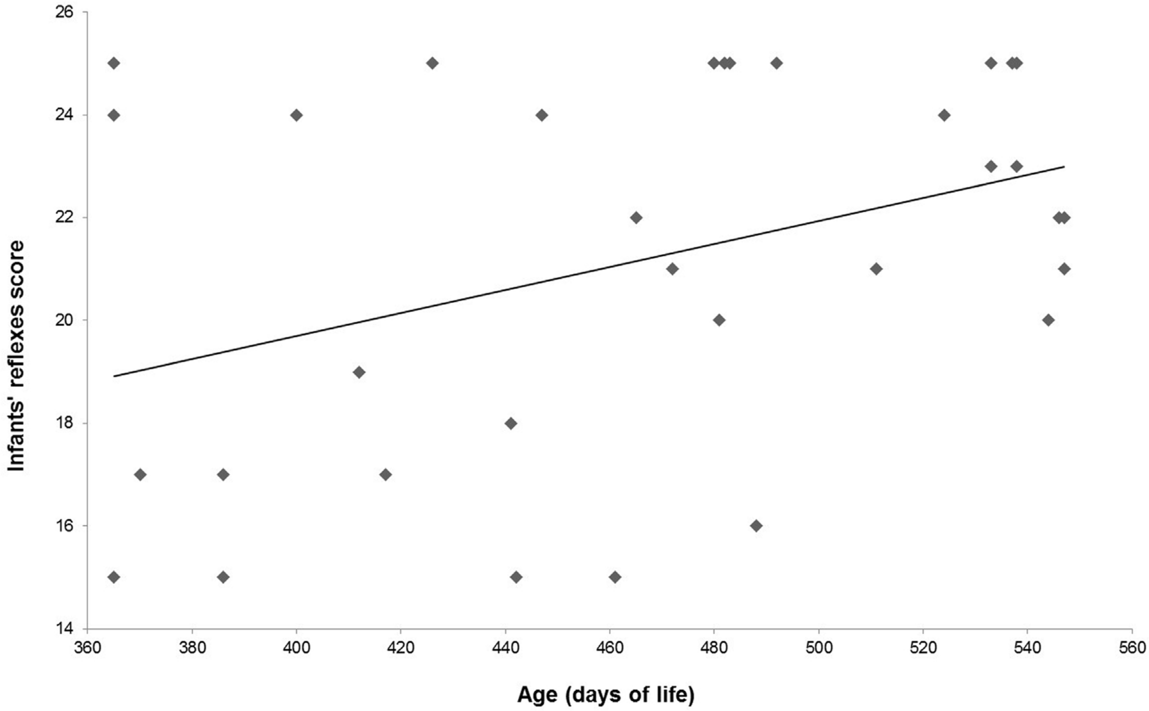

Fig. 1. Infant' reflex score correlates with age: older children have lower reflex scores; low score indicates inhibition of reflexes.

3.2. Data analyses

3.2.1. Primitive reflexes and motor repertoire

After confirming the relationship between the persistence of primitive reflexes and age, we explored whether persistence of grasping and rooting reflexes affected infants' ability to perform actions and communicative gestures that required fine hand and mouth movements independently of any age effects. Participants were divided into two groups on the basis of their score on the primitive reflexes scale. Participants who scored above average (i.e., showed relative high persistence of primary reflexes) made up the 'high persistence of reflexes' (HPR) group (n = 13, M reflex score = 15.69, SD = 5.06), whereas those with below average scores comprised the 'low persistence of reflexes' (LPR) group (n = 21, M reflex score = 23.62, SD = 1.53).

A one-way ANOVA on motor score (hand and mouth actions), with reflex group (HPR; LPR) as a between-subjects factor and age as a covariate revealed a main effect of reflex group ($F_{(1,31)} = 14.514$, $p = 0.001$ $\eta_p{}^2 = 0.319$) which was independent of age ($F_{(1,31)} = 1.222$, $p > 0.05$). These findings revealed that LPR participants had higher motor scores than HPR participants ($t_{(32)} = -4.814$, $p = 0.0001$; Cohen's $d = 1.65$), suggesting that the persistence of primitive reflexes reduces infants' performance in interactions with objects (i.e., actions) and people (i.e., communicative gestures).

3.2.2. Primitive reflexes and subclinical autistic traits

We also investigated the relationship between persistence of primary reflexes in infants and parental self-reports of subclinical autistic traits. These analyses are based on data from 28 of the 31 participants, as in the case of three children at least one parent provided an incomplete AQ questionnaire (missing responses for more than five items). The Shapiro-Wilk distribution test of maternal (S-W = 0.967, $df = 28$, $p = 0.492$) and paternal (S-W = 0.958, $df = 28$, $p = 0.321$) AQ scores confirmed that subclinical autistic traits were continuously distributed in our sample, as in the general population. Using the normative data from the Italian validation of the questionnaire (Ruta, Mazzone, Mazzone, Wheelwright, & Baron-Cohen, 2012) the parents' AQ scores were transformed into z-scores. Infants' reflex scores were also transformed into z-scores. The correlations between infant reflex score and maternal and paternal AQ scores were calculated (all scores expressed as z-scores). Infant reflex score was correlated with both paternal AQ score ($r = -0.543$; $p = 0.003$) and maternal AQ score ($r = -0.388$; $p = 0.041$), suggesting that parents with higher levels of subclinical autistic traits tend to have infants who show more persistent primitive reflexes than parents with lower levels of subclinical autistic traits (Fig. 2).

To explore the relationship between persistence of primary reflexes in infants and parental levels of subclinical autistic traits we conducted an ANOVA with maternal and paternal AQ scores as covariates and infant reflex score as the dependent variable. As expected there was a main effect of paternal AQ score ($F_{(1,24)} = 7699$, $p = 0.011$ $\eta_p{}^2 = 0.243$), indicating that infant reflex score is related to paternal AQ score. This effect has been confirmed independently by participants' age ($F_{(1,24)} = 3.120$, $p > 0.05$).

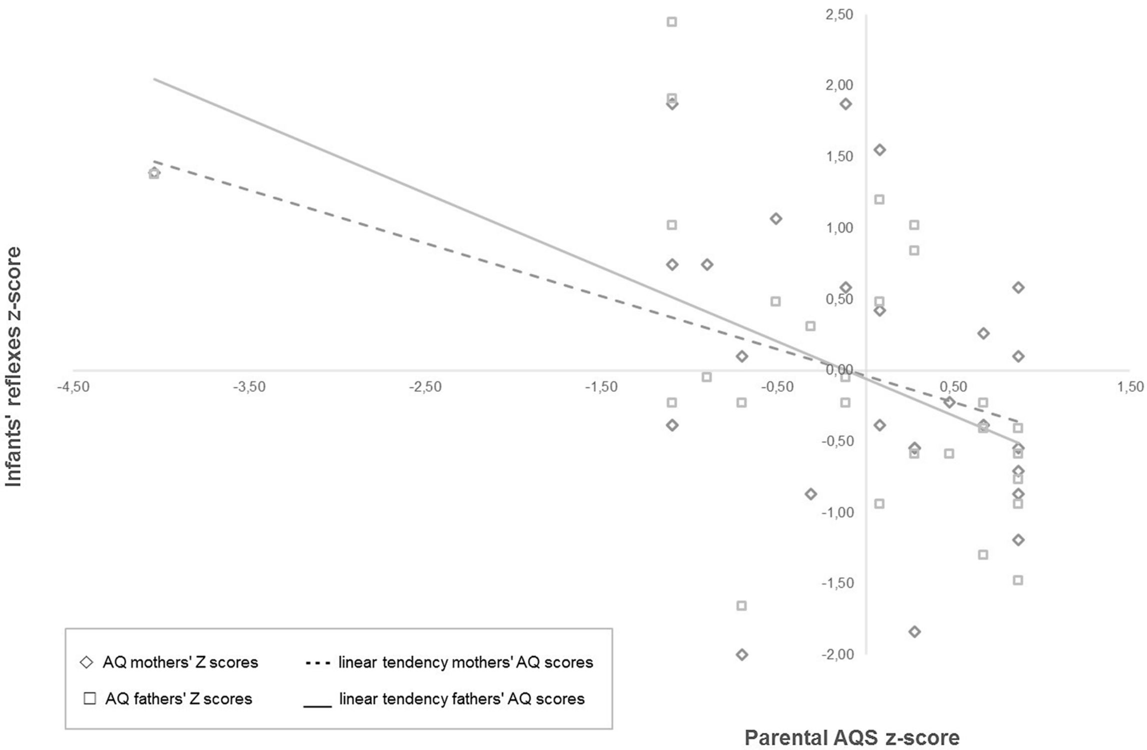

Fig. 2. Infant reflex score is correlated with parental AQ score; children with more persistent primary reflexes have parents with higher levels of subclinical autistic traits.

Table 2
Correlational matrix. The table shows the correlations between infant reflex score and maternal and paternal scores on the two selected ASQ subscales (see table footnote for significance level).

	Reflexes Score	Maternal Social Skills AQ	Maternal Communication AQ
Reflexes Score	1	−0.456**	−0.204
Paternal Social Skills AQ	−0.421**	0.086	0.273
Paternal Communication AQ	−0.457**	0.055	0.276

*** $p < 0.001$.
** $p < 0.05$.

We focused on two of the five AQ subscales, social skills and communication, because previous studies have found social and communicative impairments in the siblings and parents of individuals with ASD (e.g., Bolton et al., 1994; Constantino et al., 2006; Piven et al., 1997). Most importantly, recent evidence suggests that these domains are mainly connected with the characteristics of the offspring, when they presents a diagnosis of autism (Bishop et al., 2004; Wheelwright, Auyeung, Allison, & Baron-Cohen, 2010).

Infant reflex score was correlated with paternal scores on both the social skills ($r = -0.421$, $p = 0.026$; n = 28) and communication subscale ($r = -0.457$, $p = 0.014$; n = 28) and with maternal score only on the social skills subscale ($r = -0.456$, $p = 0.015$; n = 28). Taken together these correlations (*see* Table 2) suggest that infants with more persistent reflexes tend to have fathers who show more autistic-trait features in social skills and communication subscales (and its reverse), whereas mothers with lower social skills have infants with more persistent primitive reflexes (and its reverse).

3.3. General discussion

The target of the current research was to identify the relationships between the persistence of three primitive reflexes (grasping, rooting and sucking) and both the motor repertoire of 12- to 17-month-old infants and their parental subclinical autistic-like traits.

This target is relevant for at least two reasons. First, the persistence of primitive reflexes might be a promising early sign of autism that, together with the early attentional signs (Elsabbagh et al., 2013, 2009; Ronconi et al., 2014), might help to characterize the developmental course of broader phenotype of autism in infancy (e.g., *BAP*, Piven et al., 1997). In line with the Neuroconstructivist approach (Bishop, 1997; Karmiloff-Smith, 1998) we believe that small variations in the early stages of the development (i.e., the persistence of primitive reflexes) might exert negative cascading effects not only on later motor skills but also in a variety of other domains (i.e., object exploration and social and communicative behaviour).

Second, detecting early motor abnormalities might be also promising for stratification of ASD (Esposito & Pasca, 2013). Indeed depending on the task and the cohort, the proportion of ASDs children displaying motor development abnormalities varies. Esposito, Venuti, Apicella, and Muratori (2011), found that persistent postural asymmetries were present only in ~40% of children with ASDs. The variability in these deficits across the spectrum is a challenge that likely reflects the clinical and etiological heterogeneity of ASDs. At the same time, it constitutes a unique opportunity to identify disease subtypes.

Starting from these considerations, we examined in a general population of 12–17 months old infants the relationship between the persistence of primitive reflexes that involve the use of the hand and of the mouth and (1) infants' age, (2) infants motor repertoire and (3) the subclinical autistic traits measured in their parents.

Findings revealed a higher inhibition of primitive reflexes in older than in younger infants. This result sustains a maturational explanation of primitive reflexes inhibitions: as the nervous system develops, primitive reflexes are inhibited or transformed. Results revealed also the presence of primitive reflexes beyond their normal time span (12 months), confirming a previous work (McPhillips et al., 2000): the inhibition of primary reflexes can be brought at a later stage of the development than is generally accepted.

Independently by participants' age, the persistence of the primitive reflexes was significantly associated with infant's performance in both the interaction with objects (i.e. actions) and with people (i.e., communicative gestures), meaning that low scores in the primitive reflexes assessment, corresponding to elevated persistence of the reflexes, correlate with low scores in motor repertoire irrespective of the infants' age. This finding is consistent with previous studies, reveling that the persistence of the Asymmetrical Tonic Neck reflex, another primitive reflex, reduces both fine (such as fingering, shaking, rotating and transferring objects across the midline) and gross (such as rolling, creeping, crawling, riding a bicycle and catching or kicking a ball) motor abilities (McPhillips et al., 2000; McPhillips & Sheehy, 2004).

Finally, our results revealed that participants' persistence of primitive reflexes is related to subclinical autistic traits in their close relatives: parents with higher subclinical autistic traits have infants with a stronger persistence of primitive reflexes than parents with lower subclinical autistic traits. More specifically, our data suggest that infants with higher level of reflexes persistence have fathers with more autistic-like features in the social skills and communication sub-scales (and its reverse) and mothers with lower social skills (and its reverse). Altogether the results of this study is in line with all those studies that have suggested to observe the motor domain as a promising early sign of ASD (Bhat et al., 2011, 2012; Kaur et al., 2015; Koterba et al., 2014; LeBarton & Iverson, 2013) and also for stratification of ASD (Esposito & Pasca, 2013).

There are limitations and cautions associated with the current study. First, the finding here reported were not specific to infants later diagnosed with ASD, but concerns the relationship between reflex persistence in typical population and ASD endophenotype of their parents. Endophenotype refers to a trait that occurs more commonly in affected family members of a risk group than in the general population. Thus, endophenotypes are heritable characteristics that may have a genetic relation to ASD without however predicting full diagnosis (Szatmari et al., 2007; Viding & Blakemore, 2007). Therefore, to better understand the role of primitive reflexes persistence on later atypical development, future research should be focused on the reflexes presence in infants who are more likely to develop ASD (i.e., infants with siblings already diagnosed).

The second issue regards the sample size (n = 34) that is rather small and therefore it may not adequately represent a typical population of infants. Our findings require replication with larger number of infants and longer period of observation.

The third issue regards the experimental design. Here we compared two groups of infants with different age (i.e., younger vs. older than 15 months), but it is clear that a deeper understanding of developmental trajectories requires individual outcomes that can be obtained only collecting data longitudinally across different ages. For instance, in typical development the inhibition of the primitive reflexes promotes efficient postural control: How does the persistence of primitive reflexes interfere with postural development? How many infants with a high persistence of primitive reflexes show also postural impairments?

Despite these limitations, and taking in account the relative ease to observe primitive reflexes (for both parents and paediatricians), we believe that our findings suggest that the persistence of primitive reflexes might be a promising marker that shows the way forward in developing more effective early identification and screening measures.

Conflict of interests

The authors declare that they have no conflict of interests.

Acknowledgements

We are extremely thankful to all the families that took part in the present study. We also have to thank the nurseries that hosted us. The present research was supported by the Progetti di Eccellenza grant from the CARIPARO Foundation, Italy (rep. no. 1873/2012).

References

Allen, M. C., & Capute, A. J. (1989). Neonatal neurodevelopmental examination as a predictor of neuromotor outcome in premature infants. *Pediatrics*, *83*(4), 498–506.

Baron-Cohen, S. (1995). *Mindblindness: An essay on autism and theory of mind*. Cambridge, MA: MIT Press.

Baron-Cohen, S. (2002). The extreme male brain theory of autism. *Trends Cognitive Science*, *6*, 248–254.

Baron-Cohen, S. (2003). *The essential difference: Men, women and the extreme male brain*. London: Penguin.

Baron-Cohen, S., Cassidy, S., Auyeung, B., Allison, C., Achoukhi, M., Robertson, S., et al. (2014). Attenuation of typical sex differences in 800 adults with autism vs. 3900 controls. *PLoS One*, *9*(7), e102251.

Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001). The autism-spectrum quotient (AQ): Evidence from Asperger syndrome/high-functioning autism, males and females, scientists and mathematicians. *Journal of Autism and Developmental Disorders*, *31*(1), 5–17.

Belmonte, M. K., Gomot, M., & Baron-Cohen, S. (2010). Visual attention in autism families: 'unaffected' sibs share atypical frontal activation. *Journal of Child Psychology and Psychiatry*, *51*(3), 259–276.

Bhat, A. N., Galloway, J. C., & Landa, R. (2012). Relation between early motor delay and later communication delay in infants at risk for autism. *Infant Behavior and Development*, *35*, 838–846.

Bhat, A. N., Landa, R. J., & Galloway, J. C. (2011). Current perspectives on motor functioning in infants, children, and adults with autism spectrum disorders. *Physical Therapy*, *91*(7), 1116–1129.

Bishop, D. V. M. (1997). Cognitive neuropsychology and developmental disorders: Uncomfortable bedfellows. *The Quarterly Journal of Experimental Psychology Section A*, *50*, 899–923.

Bishop, D. V., Maybery, M., Maley, A., Wong, D., Hill, W., & Hallmayer, J. (2004). Using self-report to identify the broad phenotype in parents of children with autistic spectrum disorders: A study using the autism-spectrum quotient. *Journal of Child Psychology and Psychiatry*, *45*(8), 1431–1436.

Bolton, P., Macdonald, H., Pickles, A., Rios, P. A., Goode, S., Crowson, M., et al. (1994). A case-control family history study of autism. *Journal of Child Psychology and Psychiatry*, *35*(5), 877–900.

Capute, A. J., Palmer, F. B., Shupiro, B. K., Wuchtel, R. C., Ross, A., & Accurdo, P. J. (1984). Primitive reflex profile: A quantitation of primitive reflexes in infancy. *Developmental Medicine & Child Neurology*, *26*(3), 375–383.

Castiello, U., Becchio, C., Zoia, S., Nelini, C., Sartori, L., Blason, L., et al. (2010). Wired to be social: The ontogeny of human interaction. *PLoS One*, *5*(10), e13199.

Constantino, J. N., Lajonchere, C., Lutz, M., Gray, T., Abbacchi, A., McKenna, K., et al. (2006). Autistic social impairment in the siblings of children with pervasive developmental disorders. *American Journal of Psychiatry*, *163*(2), 294–296.

Constantino, J. N., & Todd, R. D. (2003). Autistic traits in the general population: A twin study. *Archives of General Psychiatry*, *60*(5), 524–530.

Dawson, G., Webb, S., Schellenberg, G. D., Dager, S., Friedman, S., Aylward, E., et al. (2002). Defining the broader phenotype of autism: Genetic, brain, and behavioral perspectives. *Development and Psychopathology*, *14*(3), 581–611.

Dawson, G., Webb, S. J., Wijsman, E., Schellenberg, G., Estes, A., Munson, J., et al. (2005). Neurocognitive and electrophysiological evidence of altered face processing in parents of children with autism: Implications for a model of abnormal development of social brain circuitry in autism. *Development and Psychopathology*, *17*(3), 679–697.

Dubowitz, L. M. S., Dubowitz, V., & Mercuri, E. (1999). *The neurological assessment of the preterm & full-term newborn infant* (2nd ed.). London: Mac Keith Press.

Elsabbagh, M., Fernandes, J., Jane Webb, S., Dawson, G., Charman, T., & Johnson, M. H. (2013). Disengagement of visual attention in infancy is associated with emerging autism in toddlerhood. *Biological Psychiatry*, *74*, 189–194.

Elsabbagh, M., Volein, A., Holmboe, K., Tucker, L., Csibra, G., Baron-Cohen, S., et al. (2009). Visual orienting in the early broader autism phenotype: Disengagement and facilitation. *Journal of Child Psychology and Psychiatry*, *50*(5), 637–642.

Esposito, G., & Pasca, S. P. (2013). Motor abnormalities as a putative endophenotype for autism spectrum disorders. *Frontiers in Integrative Neuroscience*, *7*(43), 1–5.

Esposito, G., Venuti, P., Apicella, F., & Muratori, F. (2011). Analysis of unsupported gait in toddlers with autism. *Brain and Development*, *33*, 367–373.

Esposito, G., Venuti, P., Maestro, S., & Muratori, F. (2009). An exploration of symmetry in early autism spectrum disorders: Analysis of lying. *Brain and Development*, *31*(2), 131–138.

Fong, S. S., Tsang, W. W., & Ng, G. Y. (2012). Altered postural control strategies and sensory organization in children with developmental coordination disorder. *Human Movement Science*, *31*(5), 1317–1327.

Fournier, K. A., Hass, C. J., Naik, S. K., Lodha, N., & Cauraugh, J. H. (2010). Motor coordination in autism spectrum disorders: A synthesis and meta-analysis. *Journal of Autism and Developmental Disorders*, *40*(10), 1227–1240.

Gernsbacher, M. A., Sauer, E. A., Geye, H. M., Schweigert, E. K., & Goldsmith, H. H. (2008). Infant and toddler oral- and manual motor skills predict later speech fluency in autism. *Child Psychology Psychiatry*, *49*(1), 43–50.

Geuze, R. H. (2003). Static balance and developmental coordination disorder. *Human Movement Science*, *22*(4), 527–548.

Goddard Blythe, S. (2000). Early learning in the balance: Priming the first ABC. *Support for Learning*, *15*(4), 154–158.

Goddard Blythe, S. (2002). *Reflexes, learning and behavior: A window into the child's mind*. Fern Ridge Press.

Goddard Blythe, S. (2011). Neuro-motor maturity as an indicator of developmental readliness for education. *TAC Journal*, *4*, 12.

Holt, K. S. (1994). *Child development: Diagnosis and assessment*. Newness: Butterworth-Heinemann.

Iverson, J. M. (2010). Developing language in a developing body: The relationship between motor development and language development. *Journal of Child Language*, *37*, 229–261.

Iverson, J. M., & Fagan, M. K. (2004). Infant vocal-motor coordination: Precursor to the gesture-speech system? *Child Development*, *75*(4), 1053–1066.

Iverson, J. M., Capirci, O., & Caselli, M. C. (1994). From communication to language in two modalities. *Cognitive Development*, *9*(1), 23–43.

Iverson, J. M., & Thelen, E. (1999). Hand, mouth and brain. The dynamic emergence of speech and gesture. *Journal of Consciousness Studies*, *6*(11–12), 19–40.

Jordan-Black, J. A. (2005). The effects of the primary movement programme on the academic performance of children attending ordinary primary school. *Journal of Research in Special Educational Needs*, *5*(3), 101–111.

Karmiloff-Smith, A. (1998). Development itself is the key to understanding developmental disorders. *Trends in Cognitive Sciences*, *2*(10), 389–398.

Kaur, M., Srinivasan, S., & Bhat, A. (2015). Atypical object exploration skills in infants at-risk for autism between 6–15 months of age. *Frontiers in Psychology*, *6*(798).

Khan, O. A., Garcia-Sosa, R., Hageman, J. R., Msall, M., & Kelley, K. R. (2014). Core concepts: Neonatal neurological examination. *NeoReviews*, *15*(8).

Koterba, E. A., Leezenbaum, N. B., & Iverson, J. M. (2014). Object exploration at 6 and 9 months in infants with and without risk for autism. *Autism*, *18*(2), 97–105.

LeBarton, E. S., & Iverson, J. M. (2013). Fine motor skill predicts expressive language in infant siblings of children with autism. *Developmental Science*, *16*(6), 815–827.

Leonard, H. C., & Hill, E. L. (2014). Review: The impact of motor development on typical and atypical social cognition and language: A systematic review. *Child and Adolescent Mental Health*, *19*(3), 163–170.

Libertus, K., & Landa, R. J. (2014). Scaffolded reaching experiences encourage grasping activity in infants at high risk for autism. *Frontiers in Psychology*, *5*, 1071.

McDuffie, A., Turner, L., Stone, W., Yoder, P., Wolery, M., & Ulman, T. (2007). Developmental correlates of different types of motor imitation in young children with autism spectrum disorders. *Journal of Autism and Developmental Disorder*, *37*(3), 401–412.

McPhillips, M., Hepper, P. G., & Mulher, G. (2000). Effects of replicating primary-reflex movements on specific reading difficulties in children: A randomised, double-blind,controlled trial. *The Lancet*, *355*(12), 537–541.
McPhillips, M., & Jordan-Black, J. A. (2007). Primary reflex persistence in children with reading difficulties (dyslexia): A cross-sectional study. *Neuropsychologia*, *45*, 748–754.
McPhillips, M., & Sheehy, N. (2004). Prevalence of persistent primary reflexes and motor problems in children with reading difficulties. *Dyslexia*, *10*(4), 316–338.
Nickel, L. R., Thatcher, A. R., Keller, F., Wozniak, R. H., & Iverson, J. M. (2013). Posture development in infants at heightened versus low risk for autism spectrum disorders. *Infancy*, *18*(5), 639–661.
Ozonoff, S., Young, G. S., Goldring, S., Greiss-Hess, L., Herrera, A. M., & Rogers, S. J. (2008). Gross motor development, movement abnormalities, and early identification of autism. *Journal of Autism and Developmental Disorder*, *38*(4), 644–656.
Parfrey, K., Gibbons, S. G. T., Drinkwater, E. J., & Behm, D. G. (2014). Effect of head and limb orientation on trunk muscle activation during abdominal hollowing in chronic low back pain. *BMC Musculoskeletal Disorders*, *15*(1).
Pavão, S. C., Neves dos Santos, A., Woollacott, M. H., & Cicuto Ferreira Rocha, N. A. (2013). Assessment of postural control in children with cerebral palsy: A review. *Research in Developmental Disabilities*, *34*(5), 1367–1375.
Piven, J., Palmer, P., Landa, R., Santangelo, S., Jacobi, D., & Childress, D. (1997). Personality and language characteristics in parents from multiple-incidence autism families. *American Journal of Medical Genetics*, *74*(4), 398–411.
Ronconi, L., Facoetti, A., Bulf, H., Franchin, L., Bettoni, R., & Valenza, E. (2014). Paternal autistic traits are predictive of infants visual attention. *Journal of Autism and Developmental Disorders*, *44*(7), 1556–1564.
Ruta, L., Mazzone, D., Mazzone, L., Wheelwright, S., & Baron-Cohen, S. (2012). The autism-spectrum quotient—Italian version: A cross-cultural confirmation of the broader autism phenotype. *Journal of Autism and Developmental Disorders*, *42*(4), 625–633.
Ruzich, E., Allison, C., Smith, P., Watson, P., Auyeung, B., Ring, H., et al. (2015). Measuring autistic traits in the general population: A systematic review of the autism-spectrum quotient (AQ) in a nonclinical population sample of 6,900 typical adult males and females. *Molecular Autism*, *6*(2), 2–12.
Schmitz, C., Martineau, J., Barthélémy, C., & Assaiante, C. (2003). Motor control and children with autism: Deficit of anticipatory function? *Neuroscience Letters*, *348*(1), 17–20.
Stone, W. L., Ousley, O. Y., Yoder, P. J., Hogan, K. L., & Hepburn, S. L. (1997). Nonverbal communication in two- and three-year-old children with autism. *Journal of Autism and Developmental Disorders*, *27*(6), 677–696.
Sucksmith, E., Roth, I., & Hoekstra, R. (2011). Autistic traits below the clinical threshold: Re-examining the broader autism phenotype in the 21st century. *Neuropsychology Review*, *21*(4), 360–389.
Szatmari, P., Maziade, M., Zwaigenbaum, L., Mérette, C., Roy, M. A., Joober, R., et al. (2007). Informative phenotypes for genetic studies of psychiatric disorders. *American Journal of Medical Genetics Part B: Neuropsychiatric Genetics*, *144*(5), 581–588.
Teitelbaum, O., Benton, T., Shah, P. K., Prince, A., Kelly, J. L., & Teitelbaum, P. (2004). Eshkol–Wachman movement notation in diagnosis: The early detection of Asperger's syndrome. *Proceedings of the National Academy of Sciences of the United States of America PNAS*, *101*(32), 11909–11914.
Teitelbaum, P., Teitelbaum, O., Nye, J., Fryman, J., & Maurer, R. G. (1998). Movement analysis in infancy may be useful for early diagnosis of autism. *Proceedings of the National Academy of Sciences*, *95*(23), 13982–13987.
Viding, E., & Blakemore, S. J. (2007). Endophenotype approach to developmental psychopathology: Implications for autism research. *Behavior Genetics*, *37*, 51–60.
Wang, M. V., Lekhal, R., Aarø, L. E., & Schjolberg, S. (2012). Cooccurring development of early childhood communication and motor skills: Results from a population-based longitudinal study. *Child Care Health and Development*, *40*(1), 77–84.
Watson, L. R., Crais, E. R., Baranek, G. T., Dykstra, J. R., & Wilson, K. P. (2013). Communicative gesture use in infants with and without autism: A retrospective home video study. *American Journal of Speech Language Pathology*, *22*(1), 25–39.
Wheelwright, S., Auyeung, B., Allison, C., & Baron-Cohen, S. (2010). Defining the broader, medium and narrow autism phenotype among parents using the autism spectrum quotient (AQ). *Molecular Autism*, *1*(1), 1.
Wilkinson, G. (1994). *The relationship of primitive postural reflexes to learning difficulty and underachievement (Unpublished M. Ed thesis)*. Newcastle: University of Newcastle-upon-Tyne.
Yang, M. (2004). Newborn neurologic examination. *Neurology*, *62*(7), 15–17.
Zafeiriou, D. (2004). Primitive reflexes and postural reactions in the neurodevelopmental examination. *Pediatric Neurology*, *1*, 1–8.
Zoia, S., Blason, L., D'Ottavio, G., Bulgheroni, M., Pezzetta, E., Scabar, A., et al. (2007). Evidence of early development of action planning in the human foetus: A kinematic study. *Experimental Brain Research*, *176*(2), 217–226.