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COMMUNICATION DISORDERS (J SIGAFOOS, SECTION EDITOR)

Persistence of Primitive Reflexes in Developmental Disorders

Jeff Sigafoos[1] • Laura Roche[2] • Mark F. O'Reilly[3] • Giulio E. Lancioni[4]

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Abstract

Purpose of Review Neonates present with a number of primitive reflexes that typically dissipate in later infancy. Persistence of such reflexes past infancy could indicate some type of developmental problem or compromised neurology and therefore might be predictably associated with various types of developmental disorders. The present review sought to summarize key studies investigating the persistence of primitive reflexes in individuals with cerebral palsy, attention-deficit/hyperactivity disorder, autism spectrum disorder, and other developmental disorders.

Recent Findings Several studies have shown persistence of primitive reflexes in children with cerebral palsy, attention-deficit/hyperactivity disorder, and autism spectrum disorder. Persistence of primitive reflexes varies in relation to the type and severity of symptoms in cases of cerebral palsy and attention-deficit/hyperactivity disorder and with the presence of comorbid intellectual disability in children with autism spectrum disorder. Primitive reflexes have also been shown to persist in adults with Down syndrome.

Summary Assessing primitive reflexes may be useful for advancing the understanding and early detection of developmental disorders. Additional research should seek to clarify the relation between the persistence of primitive reflexes and the type and severity of developmental disorders, as well as seeking to identify possible reflex phenotypes. Persistence of primitive reflexes might signal some type of developmental or neurological problem and may negatively impact motor development and learning. Evidence-based interventions to address the persistence of primitive reflexes are lacking, and the development of these should be a research priority.

Keywords Primitive reflexes · Cerebral palsy · Attention-deficit/hyperactivity disorder · Autism spectrum disorder

Introduction

The behavioral repertoire of the neonate is characterized by a number of distinct reflexes [1], which can be defined as "auto- matic involuntary movements that occur in response to a stim- ulus" [2, p. 1]. Indeed, there appear to be at least 27 different reflex relations that are either present at birth or which emerge within the first few weeks and months of life [3].

From a developmental perspective, human reflexes could be classified into those that are *durable* versus those that are more *transient*. Durable reflexes are generally retained throughout the lifespan. Examples include the patellar tendon (or knee-jerk) reflex, startle response, eye-blink, gag, sneez-
ing, and yawning reflexes [4–10]. Such reflexes, while essentially permanent, can diminish or become more pronounced due to aging, illness, disease, and various neuropathological conditions [9]. Consequently, assessing reflex strength has long been recognized as an important part of the neurological examination process [9].

There is another class of reflexes — present at birth or emerging in early infancy — that usually have a more temporary or transient existence. These more transient reflexes have been variously referred to as the primitive, neonatal, fetal, or developmental reflexes [10–12]. Table 1 describes a number of primitive reflexes that have been frequently reviewed in the medical and psychological literature [2, 10–12].

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✉ Jeff Sigafoos
jeff.sigafoos@vuw.ac.nz

[1] School of Education, Victoria University of Wellington, Kelburn Campus Box 600, Wellington, PO 6140, New Zealand

[2] School of Education, University of Newcastle, Newcastle, Australia

[3] Department of Special Education, University of Texas, Austin, TX, USA

[4] Department of Neuroscience and Sense Organs, University of Bari, Bari, Italy

Table 1 Examples of primitive/atypical reflex reactions

Reflex	Elicitation	Reaction	Usually disappears by
Asymmetrical tonic neck reflex (ATNR) in	Turning head/neck to the right or left	One arm extends and the other flexes classic fencing pose.	4 months of age
Babinski	Stroke sole of foot from heel to small toe and then across to hallux with a blunt object	Hallux moves upward and other toes spread	The Babinski sign represents an abnormal reaction to elicitation of the plantar reflex (see below)
Galant/truncal incurvation *reflex* stimulated	Stroking either side of the spine	Child's back flexes towards the side	12 months of age
Glabellar	Repetitive tapping on forehead	Eyes close/blink	Usually habituates within 5 taps. Persistent blinking is atypical (Myerson's sign)
Moro	Sudden loss of support, such as a rapid downward movement while being held	Arms spread slowly outwards and then return to midline. Often accompanied by crying	3 months of age 4 months
Palmar grasp	Stimulation of the palm by stroking or placing an object in the infant's hand	Rapid closing of fingers in a grasping response	of age
Plantar	Stroke sole of foot from heel to small toe and across to hallux with a blunt object	Toes flex downward	2 years of age
Rooting	Touching infant's cheek, mouth, or lips, especially with a circular motion	Turns to stimulus with open mouth and often sucking motions	3–4 months of age. Replaced by voluntary movement to source
Snout	Lightly touching or tapping outside of the lips at midline when lips are closed	Protrusion or puckering (pouting)	3–4 months of age
Sucking	Touch roof of mouth with nipple or finger, or pacifier	Child begins sucking	3–4 months of age. Replaced by voluntary sucking
Symmetrical tonic neck reflex (STNR) response	With child on hands and knees, the is elicited when the child's head flexes inward or extends outward	Arms bend and legs extend with head flex. Arms extend and legs bend when head is extended .	9–12 months of age
Tonic labyrinthine reflex/extensor tone	Holding infant up by the waist or chest Tilting head back when infant is lying on back	Infant holds head up (superman pose) Back stiffens and arches, legs stiffen and feet/toes point forward	4 months of age

Perhaps the most unique and intriguing aspect of primitive reflexes is that they typically disappear, or are greatly dimin- ished, within the first year or two of life [2]. It has been sug- gested that as the brain matures during infancy, primitive re- flexes are increasingly inhibited and replaced by voluntary motor responses [13]. Rousseau, Matton, Lexuyer, and Lahaye [14] argued that this diminishment or integration of primitive reflex patterns during early infancy plays an impor- tant role in children's motor development. Grzywniak [11] hypothesized that the transient nature of primitive reflexes not only facilitates psychomotor development but also learn- ing. For example, persistence of the asymmetrical tonic neck reflex might make it more difficult for a child retain hands-on engagement with their learning materials because the response of turning the head to the right (or left) would elicit extension (and flexing) of the respective arms.

Interestingly, while primitive reflexes usually dissipate in early infancy, they have been reported to persist well beyond infancy and even into adulthood in some typically developing individuals [10, 15, 16]. Usually, however, the persistence or reappearance of primitive reflexes is considered to be indica- tive of some type of developmental or neurological problem [10]. One might therefore expect that individuals with varying types of developmental disorders would evidence atypical re- flex reactions, including long-term persistence of one or more primitive reflexes.

The next sections of this paper summarize key studies that have investigated the persistence of primitive reflexes in indi- viduals with cerebral palsy, attention-deficit/hyperactivity dis- order, autism spectrum disorder, and other developmental dis- orders. Key studies were located by searching three databases (i.e., Google Scholar, ProQuest, and Medline) using a combi- nation of terms (e.g., *primitive reflexes* and *cerebral palsy* or *primitive reflexes* and *autism*). Studies had to provide objec- tive data on the persistence of at least one primitive reflex in individuals with cerebral palsy, attention-deficit/hyperactivity disorder, autism spectrum disorder, or another clearly identi- fied condition associated with developmental disorder. A re- view of this type is intended to reveal the extent to which primitive reflexes have been reported to persist in these pop- ulations. Future research and intervention directions are con- sidered in light of our review of these studies.

Cerebral Palsy

Cerebral palsy is a nonprogressive disorder caused by lesions in the developing brain. The condition affects muscle tone, posture, gait, and the ability to execute fluent motor move- ment [17]. Several studies have investigated the persistence of primitive reflexes in persons with cerebral palsy [18–22]. In an early influential study, Capute [18••] described the devel- opment of a standardized measure (primitive reflex profile)

and showed its utility for rating the strength of seven primitive reflexes (i.e., asymmetrical tonic neck, symmetrical neck, ton- ic labyrinthine, positive support, derotational righting, and Moro and Galant reflexes). In a subsequent study, Capute et al. [19•] assessed 53 children with cerebral palsy using the primitive reflex profile. They found that the resulting profiles had discriminant validity with respect to children's ambulation ability. These two studies by Capute and colleagues [18, 19] point to the value of adopting a standardized assessment proto- col as a means of quantifying the persistence and presentation of primitive reflexes in children with cerebral palsy. The results also indicated an inverse relation between the strength and the number of primitive reflexes retained and a child's ambulation ability. This relation suggests that the extent to which primitive reflexes persist may indicate the severity of the person's neuro- logical impairment and extent of functional limitations.

In another exemplary study, Dos Santos and Nogueira [20•] assessed 124 children (3 to 17 years of age) with spastic cerebral palsy for the persistence of four oral reflexes (i.e., rooting, suckle/swallow, biting, and gagging). They found that retention of the biting reflex was associated with more extensive motor impairment (i.e., spastic quadriplegia), whereas this reflex was absent in persons with less extensive motor impairment (i.e., hemiplegia). Retention of the biting reflex was also associated with increased risk of oral diseases, possibly because the biting reflex makes oral hygiene more difficult. This study is important in showing that retention of certain types of primitive reflexes might negatively affect the performance of certain self-care routines and compromise health outcomes.

Smith, Gossman, and Canan [21••] examined the consis- tency with which primitive reflexes could be elicited in 10 children with cerebral palsy. The children ranged from 3 to 6 years of age, and all were reported to have spastic quadri- plegia. The researchers attempted to elicit five primitive re- flexes (i.e., tonic labyrinthine, asymmetrical tonic neck, sym- metrical tonic neck, crossed extension, and Moro reflex). Attempts to elicit each reflex were undertaken when the chil- dren were exhibiting different levels of alertness. In this study, the children's levels of alertness were measured using a be- havioral state rating scale prior to attempting to elicit each reflex. It could be hypothesized that one's level of alertness could impact on the perception of eliciting stimuli. The results showed that the probability of eliciting a reflex was inversely related to the child's level of alertness. This finding suggests that when children are in certain bio- behavioral states, they are more likely to be responsive to eliciting stimuli. However, this study might have been assessing something other than the persistence of primitive reflexes, such as the children's general susceptibility to stimulation under different bio-behavioral states. In either case, the main finding of this study would seem to highlight the importance of optimizing a child's bio- behavioral state to ensure an accurate assessment of reflexive

behavior. Optimizing a child's behavioral state towards higher levels of alertness would seem especially pertinent for young children and for individuals with more severe impairments and/or comorbid intellectual disability, given that such individuals often show widely fluctuating levels of alertness [23].

In a large-scale prospective study, Zafeiriou et al. [22••] assessed the primitive reflexes of 204 infants who were considered at risk for developmental disorders. Fifty-eight of these children were eventually diagnosed with cerebral palsy, 22 with developmental retardation, and 124 were deemed developmentally normal at 2 years of age. Eight primitive reflexes (i.e., palmar grasp, plantar, Galant, asymmetrical tonic neck, suprapubic extensor, crossed extensor, Rossolimo, and heel reflex) were tested at 1, 3, 5, 7, 9, and 11 months of age and again at 2 years of age. They found that children with the spastic type of cerebral palsy showed slight retention of seven of the eight reflexes, whereas children with the athetoid type of cerebral palsy had a more marked retention of three specific reflexes (i.e., the plantar, Galant, and asymmetric tonic neck reflex). These data suggest that the number and strength of retained primitive reflexes might be a "useful diagnostic tool for early diagnosis of cerebral palsy" [22••, p. 151]. The spe- cific primitive reflexes retained might also be useful in the early and differential diagnosis of cerebral palsy, such as distinguishing between spastic versus athetoid cerebral palsy in infancy. In line with the results of Dos Santos and Nogueira [20•], the results of this study point to an interaction between the type and severity of cerebral palsy and the probability with which different primitive reflexes are likely to persist.

Overall, the collective results of these studies [18–22] suggest that many children with cerebral palsy are likely to pres- ent with abnormal reflex reactions, including persistence of a range of primitive reflexes. If the persistence of primitive re- flexes does in fact most usually indicate some type of neuro- logical problem [10], then it is perhaps not surprising that many individuals with cerebral palsy will retain some primi- tive reflexes, given that cerebral palsy is caused by lesions to the developing brain [17]. As Capute [18••] noted, the pres- ence of an atypical reflex profile might therefore represent one of the earliest detectable signs of cerebral palsy. With specific reference to the persistence of primitive reflexes, Gulati and Sondhi [17] have suggested that the extent to which primitive reflexes are retained in late infancy might be a useful diagnos- tic indicator of cerebral palsy.

While the available evidence reviewed in this section does indicate a high retention of primitive reflexes in children with cerebral palsy, there is considerable scope for future research. For example, future research could explore a wider range of primitive reflexes, beyond the relatively few that have been studied to date. Additional research could also aim to tease out relations between the persistence of various primitive reflexes and the type and severity of cerebral palsy using larger sample sizes that include children with different types and degrees of

cerebral palsy. Studies involving people with cerebral palsy and comorbid intellectual disability would seem especially important because a significant percentage of people with ce- rebral palsy are also likely to have intellectual disability [17]. The presence of comorbid intellectual disability might be ex- pected to influence the ease and speed with which primitive reflexes are successfully replaced by functional (voluntary) motor behavior, if in fact this developmental process is influenced to some degree by a learning component.

Attention-Deficit/Hyperactivity Disorder

Attention-deficit/hyperactivity disorder (ADHD) is characterized by distractibility, impulsivity, hyperactivity, and attentional deficits that can interfere with learning and general ac- ademic, social, and daily functioning [24]. Although the cause is unknown, ADHD is classified as a neurodevelopmental disorder and probably has an organic/biological basis [24, 25]. Several studies have examined the persistence of primitive reflexes in children with ADHD [26••, 27•, 28–30]. Taylor, Houghton, and Chapman [26••], for example, looked for reten- tion of four primitive reflexes in a sample of 54 (7- to 10-year- old) boys with ADHD in comparison to a sample of 55 typically developing boys. The Moro, tonic labyrinthine, asymmetrical tonic neck, and symmetrical tonic neck reflexes were assessed. The results showed that children with ADHD had significantly higher reactions across all four tested reflexes compared to the typically developing children. Interestingly, retention of the tonic labyrinthine and asymmetrical tonic neck reflexes was associated with lower mathematical achievement among the boys with ADHD. The authors suggested that this finding could highlight "the potential significance of reflex retention in predicting vari- ous learning and behavioural problems experienced by school-aged children" [26••, p. 35].

In another relevant study, Konicarova and Bob [27•] sought to determine whether persistence of the Moro and Galant reflexes "play a role in Attention Deficit and Hyperactivity Disorder (ADHD)" (p. 135). They therefore tested for the presence of the Moro and Galant reflexes in 20 children with ADHD and 20 typically developing children. There were equal numbers of same-aged (8 to 10 years of age) boys and girls in both groups. The results are consistent with those reported by Taylor et al. [26••]. Specifically, chil- dren with ADHD showed significantly greater retention of both the Moro and Galant reflexes compared to the typically developing children. The authors suggested that persistence of the Moro and Galant reflexes in ADHD might be due to a complex process that disrupts the child's ability to inhibit and regulate neural functions. Somewhat surprisingly, no gen- der differences were found. This is surprising because girls with ADHD are generally less hyperactive than diagnosed boys [28]. The lack of gender differences could possibly

indicate that the retention of primitive reflexes might have some type of dysregulation effect on attentional processes and perhaps also on the overall levels of motor activity.

A second study by Konicarova and colleagues [29] concentrated on assessing persistence of the asymmetric tonic neck reflex in a sample of 60 children with ADHD who, importantly, had previously received ADHD medication. The sample ranged from 8 to 11 years of age and consisted of 33 boys and 27 girls. Thirty typically developing children (8 to 11 years, 16 boys/14 girls) served as the comparison group. All children were assessed for the presence of the asymmetric tonic neck reflex. The severity of ADHD symp- toms was also assessed using the children's parent question- naire (CPQ). Reflex reactions were rated on a 3-point scale with higher scores representing a more pronounced reaction. The CPQ [30] contains 93 items that ask informants to rate a wide range of ADHD symptoms (e.g., conduct problems, anx- iety, impulsivity–hyperactivity, and learning problems). In this study, parents served as informants for the CPQ. The authors reported a significant correlation between a child's reflex scores and ADHD symptoms. That is, children who showed a more pronounced reflex response were also rated higher on a majority of ADHD symptoms. The authors interpreted these data as further evidence that the persistence of primitive reflexes might indicate a disinhibition process [27•], adding that inhibition problems might stem from "fron- tal lobe damages" [29, p. 768]. Establishing the validity of this claim will require additional research.

A third study by the Konicarova group [31] continued the theme of comparing the persistence of primitive reflexes in children with and without ADHD. This third study targeted the symmetric tonic neck reflex and the asymmetric tonic neck reflex. The study was unique in focusing only on girls who had not received any ADHD medication. The samples includ- ed 35, 8- to 11-year-old girls with ADHD and 30 similarly aged girls without ADHD. As in the previous study [29], the girls' reflex reactions were rated on Likert-type scales, and parents rated the child's ADHD symptoms using the CPQ [30]. The results were consistent with the team's previous findings [27•, 29]. That is, children with ADHD showed greater retention of primitive reflexes compared to typically developing children. There was also a significant relation be- tween the magnitude of the child's reflex reaction and parents' ratings of ADHD symptoms.

Overall, these studies suggest that school-aged children with ADHD appear to be more likely to show persistence of the Moro, tonic labyrinthine, asymmetrical tonic neck, and symmetrical tonic neck reflex when compared to same-aged peers without ADHD. This finding does not appear to be a by- product or side effect of ADHD medication but does seem to relate to the severity of ADHD symptoms. The greater persis- tence of primitive reflexes among children with ADHD has been suggested to stem from various possible factors, such as

failure to attain important developmental milestones [27•], delayed cortical maturation [32], and problems with higher levels of coordination of the central nervous system [29, 33]. There are significant limitations in the ADHD/primitive reflex literature. First, three of the four studies were generated by the same research team, indicating the need for indepen- dent replications. Second, a relatively narrow age range (8 to 11 years of age) has been included in these studies. It is there- fore unclear if the primitive reflexes shown by the children in these studies would persist into adolescence and adulthood. Third, it is unclear if the primitive reflexes shown by school- aged children have been retained since infancy or have reappeared at some point after having disappeared in infancy. The reappearance of primitive reflexes has been reported in the elderly [34] and in persons with age-associated neurolog- ical conditions, such as Alzheimer's disease [35] and demen- tia [36]. Another gap in the ADHD/primitive reflex literature is the lack of studies into the effects of retained primitive reflexes on learning and more general areas of adaptive func- tioning. An important limitation is that the studies to date have attempted to elicit a relatively small number of reflexes. Longitudinal studies by additional research teams in which a wider range of primitive reflexes are assessed at regular inter- vals (from infancy to adulthood) — and that measure a wider range of learning and behavioral correlates — would be re- quired to address these gaps and limitations. Comorbidity would be another important variable to consider in future re-search. This would be important given that ADHD is highly concurrent with a range of other conditions, such as develop- mental coordination disorder, learning difficulties, and speech–language delay. It would be useful to determine if there are differences in the persistence of different types of primitive reflexes among persons with ADHD and varying comorbidities. As yet, these types of relations have not been widely examined in the literature.

Autism Spectrum Disorder

Autism spectrum disorder (ASD) is a developmental condi- tion characterized by significant social skills and communica- tion impairments, repetitive behavior, and a restricted range of interests [25]. ASD is considered to have a neurobiological basis related to both genetic and environmental factors impacting on the developing brain [37]. Despite the increasing numbers of children being identified with ASD and an explo- sion of research into its nature, assessment, and treatment [37, 38], there is surprisingly little research into the persistence of primitive reflexes in individuals with this diagnosis, although this phenomenon has been widely recognized by autism re-searchers [39–42].

In an important early study, Minderaa and colleagues [43••] reported on the persistence of primitive reflexes in samples of

children and young adults with and without ASD. The ASD sample (n = 42) consisted of 31 males and 11 females ranging from 8 to 28 years old (mean age 19.5 years). The control group also had 42 people (30 males and 12 females) of comparable age (range = 7 to 29 years old, mean = 19.6 years). Eight reflexes were tested (i.e., snout, sucking, tactile rooting, visual rooting, grasp, palmomental, glabellar, and nuchocephalic). Significant differences were found with respect to the persistence of the snout and visual rooting reflexes. Specifically, these two reflexes were observed in 81% (male) and 78.6% (female) of the individ- uals with ASD but only in 14.3% and 0% of the controls, respec- tively. There were no significant differences on any of the other reflexes. This probably reflects a floor effect as these reflexes were reported for very few participants overall. In the ASD group, age, gender, and use of medication were not significantly related to the presence or absence of these primitive reflexes. In an insightful discussion point, the authors speculated that the high prevalence with which these two "oral" reflexes persisted might have some significance for understanding the speech and language deficits associated with ASD [43••, p. 414]. In line with this suggestion, it could be useful to test for persistent primitive reflexes as part of a more general speech language assessment.

An interesting comparison by de Bildt et al. [44•] examined the persistence of the visual rooting reflex in 155 individuals with ASD plus intellectual disability versus 65 individuals with intellectual disability only. Both samples were predomi- nantly male (72.9% and 64.6%, respectively) and included a fairly wide age range (3 to 20 years with a mean of 11 years). In line with Minderaa et al. [43••], a significant percentage of the ASD participants showed persistence of the visual rooting reflex (43.9%). Indeed, the ASD plus intellectual disability group was significantly more likely to have the visual rooting reflex (43.9%) than the intellectual disability only group (24.6%). However, for both groups, the reflex was more often present in those with severe/profound versus mild/moderate intellectual disability. Comorbid intellectual disability would thus appear to be of relevance to the persistence of the visual rooting reflex in people with ASD.

In a more recent study, Accardo and Barrow [45•] assessed toe walking and the tonic labyrinthine reflex in a sample of 61 children newly diagnosed with ASD. The children ranged in age from 19 to 36 months of age (median = 31 months), and most (88%) were boys. The tonic labyrinthine reflex was rated as abnormal in 23 of the 61 children (37.7%). Of significance is that children with an abnormal tonic labyrinthine reflex were twice as likely to be rated as having moderate to high levels of toe walking. The researchers suggested that persis- tence of the tonic labyrinthine reflex might hinder the devel- opment of normal/fluent ambulation and ". . . contribute to persistent toe walking" [45•, p. 608].

In another more recent study, Chinelloa, Valentina Di Gangib, and Eloisa Valenzab [15] studied 34 infants (15 boys/19 girls) ranging from 12 to 17 months of age. Infants

were tested for the presence of the grasping, rooting, and sucking reflexes. They found an inverse relation between in- fants' motor skill development (e.g., fine motor skills and gesturing) and persistence of primitive reflexes. They also found a relation between parental autism traits and infants' reflex reactions. Specifically, infants who had parents with higher levels of [subclinical] autistic traits showed more per- sistent primitive reflexes. However, it is important to note that this study included infants who did not have any diagnoses. Therefore, these results might not be applicable to children later diagnosed with ASD. Caution should also be taken be- cause, with an upper age limit of 17 months, the researchers might have identified delays with respect to disappearance of primitive reflexes rather than longer-term persistence of prim- itive reflexes. Still, the relation to parental traits suggests that the persistence or delayed disappearance of primitive reflexes might serve as an early indicator of some possible familial link to the autism spectrum.

The overall results of these studies suggest that the snout, visual rooting, and tonic labyrinthine reflexes might persist in some children diagnosed with ASD. The presence of such reflexes could possibly therefore represent an early sign of ASD. An intriguing finding was the relation between the se- verity of comorbid intellectual disability and the likelihood of retaining the visual rooting reflex [44•]. Future research should examine if any similar such relations might exist be- tween the persistence of primitive reflexes and the severity of ASD symptoms.

Other Developmental Disorders

There appear to be relatively few studies into the persistence of primitive reflexes among individuals with other types of developmental disorders. Sand, Mellgren, and Hestnes [46•] reported higher rates of the palmomental (47% of sample) and snout (14% of sample) reflex in a sample of 30 adults with Down syndrome, compared to 45 control participants (7 and 0% of the sample, respectively). Bilbilaj, Gjipali, and Shkurti [47] reported high retention rates (ranging from 57% to 100%) for eight different reflexes (asymmetric tonic neck, tonic lat- eral, symmetrical tonic neck, Galant, Moro, rooting, sucking, and Palmar) in students with various learning disorders. However, this study should be interpreted with caution be- cause the sample was relatively small (n = 14) and included students with a wide range of conditions (i.e., ASD, ADHD, dyslexia, and oral disorder). Another study examined primi- tive reflexes in 67 high-risk infants due to being premature or needing intensive care [48]. Abnormal reactions to elicitation of the Moro, Babinski, and sucking reflexes were common, highlighting the clinical relevance of reflex reactions in iden- tifying infants at risk for developmental delay/disorder.

Overall, there is a need for additional research into the persistence of primitive reflexes among individuals with, or at risk for, developmental delay/disorder. A good starting point would be to include participants representing a range of syndrome conditions and risk factors. For example, it could be informative to compare the range and extent to which primitive reflexes are retained in individuals from different syndrome groups (e.g., Angelman, fetal alcohol, fragile X, 22q11.2 deletion, and Williams syndrome). Such studies might lead to the discovery of reflex phenotypes, which could be useful for early and differential diagnosis.

Conclusion

The results of the studies reviewed in this paper suggest that primitive reflexes are likely to persist in some individuals with cerebral palsy, ADHD, ASD, and probably also in people with a number of other developmental disorders. Absent, persistent, or atypical reflex reactions might provide a useful indicator of risk for developmental delay, developmental disorder, learning problems, and likely functional limitations. Early, regular, and comprehensive assessments of children's reflex reactions, including assessment of primitive reflexes, might provide useful diagnostic information and therefore should be encouraged.

An important intervention objective would be to minimize any negative impact on development, learning, and adaptive be- havior functioning that might arise should primitive reflexes per- sist past infancy or reappear at some later stage of development. At least three possible intervention approaches could be envisioned: (a) preventing elicitation, (b) teaching individuals to inhibit their own reflex reactions, and/or (c) shaping existing reflex reactions into the service of a functional (voluntary) re- sponse. While each of these options has been mooted [2, 14, 49], well-controlled intervention studies are lacking and could thus be seen as a priority area for future research.

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Declarations

The authors have complied with the relevant ethical standards of their respective universities.

Conflict of Interest The authors declare no competing interests.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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