Research Article

Developmental Language Disorder and Uninhibited Primitive Reflexes in Young Children

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Purpose: Developmental language disorder (DLD) is a developmental disorder where children fail to acquire language in the absence of a clear cause. Many studies have reported general motor deficits in children with DLD, but no studies have uncovered a cure. The purpose of our study is to better understand the underlying motor deficits in DLD, starting from uninhibited primary reflexes—which are the most basic stage of motor development. Knowledge of this motor–language relationship should lead to earlier and more targeted interventions in young children with DLD.
Method: Children with DLD (n = 75, age range: 4–10 years) and 99 age-matched typically developing (TD) children completed a nonword repetition test to assess DLD and six other tests to assess primitive reflexes.
Results: Children with DLD demonstrated higher levels of persistent primitive reflexes compared to TD children. As the scores for neuromotor immaturity increased, nonword repetition test scores decreased (r = −.44, p < .01). Results indicated that TD children exhibited lower neuromotor immaturity (M = 7.63, SD = 3.75) compared to children with DLD (M = 13.51, SD = 4.47). All primitive reflexes (the Moro reflex, the symmetrical tonic neck reflex in flexion and in extension, the asymmetrical tonic neck reflex, the tonic labyrinthine reflex, and the Galant reflex) turned out to be statistically significantly different for the TD and DLD groups (p < .001). We also observed some differences between sexes.
Conclusions: Children with impaired language development underwent slower neuromotor development. However, further research is needed to determine whether motor intervention programs that inhibit primitive reflexes are helpful for children with DLD.

Developmental language disorder (DLD) is observed in children whose language skills, for no clear reason, develop in a nontypical manner. Notably, such significant language difficulties are not accompanied by any serious cognitive, auditory, environmental, or neurological deficits (Bishop, 1992). It is estimated that approximately 7% of the population (Smoczyńska, 2006) will experience DLD, leading to long-term consequences for child development. The deficits that are characteristic of DLD persist into adolescence and may remain noticeable even in adulthood. Numerous studies have uncovered relationships between language deficits and other factors possibly caused by DLD, such as auditory processing disorder (Ferguson et al., 2011), deficits in phonological memory (Gathercole & Baddeley, 1993), delay in neurophysiological development manifesting in delayed cognitive and motor development (Adams, 2016; Bishop & Edmundson, 1987), and impairment of cognitive executive functions (Pauls & Archibald, 2016). According to various studies, consequences of DLD include learning difficulties (DeThorne et al., 2006; Fisher, 2017; Hulme & Snowling, 2009; Koutsoftas, 2016), poorer social interactions, and a lower position in one's peer group (Leonard, 2014).

Studies concerning the co-occurrence of DLD and motor immaturity have been conducted all over the world for more than 40 years, but they vary from one another in the different diagnostic tools used to assess the disorder. Nevertheless, children with DLD are assumed to differ from typically developing (TD) children as far as motor skills are concerned. For instance, quantitative differences occur in areas of motor development, such as gross motor skills (Chuang et al., 2011; Fernell et al., 2002; Iverson & Braddock, 2011; Müürsepp et al., 2011; Powell & Bishop, 1992; Zelaznik & Goffman, 2010), fine motor skills (Bishop

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[†]The coauthor, Prof. Tadeusz Gałkowski, passed away during the revision process. He was an outstanding Polish scholar and a teacher of several generations of psychologists.

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& Edmundson, 1987; Brumbach & Goffman, 2014; Cheng et al., 2009; Chuang et al., 2011; Fernell et al., 2002; Owen & McKinlay, 1997; Powell & Bishop, 1992; Zelaznik & Goffman, 2010), general motor clumsiness (Robinson, 1991), balance (Estil et al., 2003; Fernell et al., 2002; Müürsepp et al., 2011; Powell & Bishop, 1992), bilateral coordination (Bishop, 1990; Estil et al., 2003; Vukovic et al., 2010; Vuolo et al., 2017), and imitation of positions and movements (Marton, 2009; Vukovic et al., 2010). According to one article review (Ullman & Pierpont, 2005), children with DLD—besides showing deficits on tests of fine and gross motor skills, limb mobility, coordination, and balance—showed impaired complex sequential motor skills, even when performing some motor tasks as precisely as TD children. Thus, it appears that, as far as motor development is concerned, children with DLD differ not only from TD children but also from children with articulation disorder (Müürsepp et al., 2012). Moreover, qualitative research has shown that children with DLD differ from TD children in terms of their pace of carrying out tasks, their precision, error complexity, ability to focus on motor tasks, and the relationship between accuracy of task performance and the degree of task complexity (Bishop & Edmundson, 1987; Marton, 2009; Powell & Bishop, 1992; Sanjeevan & Mainela-Arnold, 2017).

Poor fine and gross motor skills in children with DLD have not presented any connection with difficulties in rhythmic tasks (Zelaznik & Goffman, 2010) or the ability to accompany communication with gestures (Iverson & Braddock, 2011). Vuolo et al. (2017) found a relationship between bilateral coordination, language, and motor development. However, no significant differences in language abilities were found between children with DLD with typical motor development and children with DLD with motor impairment. Some studies (Cheng et al., 2009; Hill, 1998, 2001) indicate that children with developmental coordination disorder (DCD) are 3 times more likely to be diagnosed with DLD than other children. Hill (2001) assumed that the development of the locomotor system reflects regular developmental changes of the central nervous system, which means that language and motor deficits both result from general delayed development. According to the *Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition*'s diagnostic criteria (American Psychiatric Association, 2013), DCD belongs to the same group of disorders as DLD (i.e., neurodevelopmental disorders). DCD is diagnosed when a child has significant impairment in acquiring and exercising skills that require motor coordination. As in the case of DLD, DCD is diagnosed in children when the disorder is not due to other medical conditions that can cause such problems.

An increasing number of studies have found a relationship between speech and language development impairment and minimal brain dysfunction that manifests in a set of uninhibited primitive reflexes (PRs; Goddard Blythe, 2017). PRs are the most basic stage of motor development, and they appear in utero. Typically, they are inhibited in the first year of life, and until recently, it was believed that they last longer only in children with cerebral palsy or other nervous system damage (Borkowska, 2001). However, increasingly, studies have indicated that PRs may be uninhibited in older children and adults. For instance, some studies have found a statistically significant correlation between uninhibited PR presence in children over 4 years old and poor physical skills (Chinello et al., 2018; Gieysztor et al., 2018). According to Niklasson et al. (2018), PRs should be included for assessment and intervention of DCD. One study (Pecuch et al., 2018) showed that the occurrence of neuromotor disorders and persistent PRs in children with diagnosed psychomotor disorders is common. In addition, Matuszkiewicz (2016) found that, as the results of a language test became better, the chance that uninhibited PRs would appear became lower.

Brookman et al. (2013) compared groups of children with DLD, typical development, and reading difficulties (RD) in four motor tasks and discovered that the relationship between RD and motor impairment may largely be the result of a co-occurrence of DLD. The researchers claimed that RD and DLD often co-occur, whereas motor impairment that is observed in children with RD may be more a function of language impairment than reading or writing difficulties. A study by Grzywniak (2016) indicated that reading and writing difficulties are related to neuromotor immaturity (NMI), defined as a set of uninhibited PRs. In addition, Gieysztor et al. (2017) found that some healthy children retain PRs. Notably, preschool children obtain far worse results in movement integration than children of early school age, indicating that PR inhibition is related to central nervous system development. Moreover, it appears that uninhibited PRs are a significant indicator of school performance and verbal intelligence (Goddard Blythe, 2005; Jordan-Black, 2005; McPhillips & Jordan-Black, 2007). In addition, McPhillips and Sheehy (2004) uncovered a correlation between uninhibited reflexes and various deficits in a group with the highest level of NMI indicators. In a different study, reading skills considerably improved in a group of children where uninhibited PRs decreased after a specific program of physical exercises (Grzywniak, 2017).

Notably, some studies have indicated that decreased reflexes are accompanied by improved school performance (Goddard Blythe, 2005; McPhillips et al., 2000; Wahlberg & Ireland, 2005). For instance, McClelland et al. (2015) compared progress in reading, writing, and mathematics in a group of children who received motor intervention against a comparison group. In the comparison group, the increase in the percentage of children who achieved their target in standardized school tests was 3 times lower than the improvement seen in the intervention group. In addition, children from the experimental group were divided into three subgroups according to their achievements in the initial standard school tests: a top 50% subgroup, a subgroup of scores between 50% and 20%, and a bottom 20% group. The greatest progress in reading, writing, and mathematics was observed in children who were in the lowest 20% before receiving the motor intervention. This finding suggests that school performance of children with the weakest neuromotor development may benefit most from motor intervention programs.

Studies conducted on the relationship between PRs and RD (Goddard Blythe, 2005; Grzywniak, 2016, 2017; Jordan-Black, 2005; McClelland et al., 2015; McPhillips et al., 2000; McPhillips & Jordan-Black, 2007; Wahlberg & Ireland, 2005) have examined the tonic labyrinthine reflex (TLR), the asymmetrical tonic neck reflex (ATNR), and the symmetrical tonic neck reflex (STNR). These reflexes are linked to oculomotor functions and changes in muscle tension in different parts of the body during head movements. It appears that these reflexes also play significant roles in the development of children with DLD because of their relationship with head control. All three reflexes are tonic reflexes, meaning that, in changing the position of the head, the tonus of specific parts of the body also changes. According to Goddard Blythe (2017), if PRs elicited as a result of head flexion, extension, or rotation are uninhibited or if the postural reflexes depending on PRs do not fully mature, the functioning of the cerebellum will be affected. According to this theory, with the help of postural reflexes, the cerebellum can effectively control posture and motility. Uninhibited tonic PRs may temporarily hamper this control, depending on the position of the head. This may be important, as Highnam and Bleile (2011) have shown in a review of clinical studies that the cerebellum has considerable influence over language processing and other cognitive skills.

The TLR is elicited when an infant moves its head forward or backward. The forward direction causes flexion in all the limbs, while a backward direction causes extension in the limbs. This flexion response is inhibited around the age of 4 months, while the extension response is gradually inhibited from 6 weeks to 3 years of age. The TLR is thought to be a primitive response to gravity and is present in early infancy before higher systems involved in postural control have developed. Inhibition of the TLR is a gradual process and should be mostly finished during the first year of life. However, full inhibition of the TLR should occur before 3.5 years of age. In addition, a strong TLR in extension can have a negative impact on the motor aspects of feeding and speech. The head extension causes the tongue to stick out, which makes it difficult for the baby to draw the nipple into the mouth and suck and makes it difficult for an older child to swallow and articulate properly.

The ATNR is elicited by the rotation of the head, which causes arm and leg extension on the jaw side and arm and leg flexion on the occipital side. This reflex is inhibited between the fourth and sixth month of life. In addition to affecting the functioning of the cerebellum through difficult head control, the ATNR is associated with speech functions by making it difficult to insert hands and objects into the mouth when the head is turned sideways. In general, an infant with ATNR that is uninhibited on time has difficulty with tactile self-stimulation of the oral area.

The STNR is present for a short period at birth, reemerges at around 6–8 months of life, and becomes inhibited at around 11 months. This reflex helps children pick themselves up off the floor and take a quadruped position. The STNR is elicited when an infant moves its head forward or backward. In this case, moving in a forward direction causes leg extension and arm flexion, while moving in a backward direction causes leg flexion and arm extension. The STNR is thought to help with integration and inhibition of the TLR and provides the basis for stable positioning against gravity. Therefore, the STNR may play an important role in the functioning of the cerebellum.

Considering Goddard Blythe's (2017, 2018) description of PRs, other reflexes may also be significant for speech and language development. For example, the Moro reflex is elicited when infants rapidly lower their heads to below spine level. In addition, the Moro reflex causes abduction of arms, a sudden intake of breath and momentary stillness, and finally adduction of arms and, usually, crying. Unexpected vestibular stimulation is the strongest stimulus that causes the Moro reflex, but other rapid stimuli can also elicit it (e.g., loud sound, strong light, or unpleasant touch).

Importantly, the Moro reflex is inhibited between 4 and 6 months of life. Goddard Blythe (2017) assumed that inhibition of this reflex is associated with the maturation of the acoustic stapedius reflex, which protects the ears from loud sounds. The acoustic stapedius reflex develops between 2 and 4 months of age, and it consists of a contraction of the stapedius muscle of the middle ear in response to loud noise. This contraction reduces the movement of the stapes, decreases the intensity of the vibration that is transmitted to the cochlea, and reduces the intensity of sound. Weak development of the acoustic stapedius reflex can cause acoustic hypersensitivity, which can easily elicit the Moro reflex via acoustic stimuli. It seems that the Moro reflex, when not inhibited in a timely manner, can cause difficulties in the development of the acoustic stapedius reflex, and an immature acoustic stapedius reflex blocks further inhibition of the Moro reflex (Goddard Blythe, 2018). Such problems with the functioning of the Moro reflex and the acoustic stapedius reflex can affect auditory processing, thereby affecting the development of speech, language, and communication.

Furthermore, according to Rousseau et al. (2017), the Moro reflex is a ritualized behavior of nonverbal communication. These researchers found that an infant makes some gestures between the abduction and adduction phase, for example, turning the body, head, and eyes toward a parent to look for protection, which may be relevant for the early development of communication between infant and parent. Additionally, the Moro reflex can have other associations with speech. For example, according to Goddard Blythe (2018), an uninhibited Moro reflex can cause breathing irregularities, causing a tendency for rapid shallow breathing resulting in mouth breathing. A study by Junqueira et al. (2010) found that mouth breathing can cause a habitual open lips rest posture, low and forward tongue rest posture, and a lack of adequate muscle tone, all of which can affect articulation.

Another reflex that may be related to speech and language development is the Galant reflex. This reflex is elicited by tactile stimulation on one side of the spine and causes hip rotation toward the stimulus. It is inhibited between the third and ninth month of life. According to Goddard Blythe

(2018), the spinal Galant reflex may be a primitive conductor of sound in the womb. During uterine life, sound vibrations stimulate the skin, and the Galant reflex helps transmit vibration from the skin to the ear through a combination of skin and bone conduction. Notably, there may be a link between middle ear infections and the Galant reflex as well. Goddard Blythe conducted a study involving children with speech and language impairments. Participants were involved in auditory integration training, which is a sound therapy method designed to improve auditory processing. PRs were tested in these children, and it was found that, after auditory training, the Galant reflex level had decreased. Such connections with auditory processing also point to a relationship between the Galant reflex and speech and language development in children.

Importantly, the relationship between DLD and motor development must be assessed, as previous studies have not provided consistent results in this regard (Ullman & Pierpont, 2005; Vuolo et al., 2017). Thus, based on the aforementioned literature, the purpose of this study is to determine whether uninhibited PRs may be an underlying link to the observed language–motor deficits in children with DLD compared to their TD peers. We hypothesized that children with DLD will have more uninhibited PRs and higher levels of them than TD children, meaning that children with DLD will have greater NMI than TD children. We also expected to find some differences in the results of boys' and girls' reflex levels. The study by Gieysztor et al. (2018) found that neuromotor development and the level of reflex inhibition were higher in girls than in boys. Although this difference turned out to be statistically insignificant, we expected the same trend. Additionally, McPhillips and Sheehy (2004) found higher ATNR levels in boys than in girls in a group of children with RD. Furthermore, DLD is 1.5–3 times more likely to occur in boys than in girls (Broomfield & Dodd, 2004; Tomblin et al., 1997). Thus, this study addressed three specific questions:

1. Do children with DLD have higher uninhibited PR levels than TD children?
2. Which PRs are significantly higher in children with DLD than TD children?
3. Do boys have higher uninhibited PR levels than girls?

Method

Participants

A total of 174 children (132 boys and 42 girls, M_{age} = 7.2 years, range: 4.2–10.6) participated in this research. There were 75 children in the DLD group (77% boys, 23% girls) and 99 TD children (75% boys, 25% girls). According to the parents' initial statements, all TD children and children with DLD had an intellect in the normal range, did not have a diagnosis of autism spectrum disorder, had hearing in the normal range, did not have acquired brain injuries, and were monolingual Polish speakers.

The DLD group included children with a diagnosis of specific language impairment (SLI) or developmental aphasia, which was made by speech and language pathologists, but after a prior medical diagnosis in accordance with the International Classification of Diseases, 10th Revision of expressive language disorder (F80.1) or mixed receptive–expressive language disorder (F80.2). In Poland, it is difficult to diagnose children with DLD due to legal conditions regarding additional support for children with DLD at school. Children with significant speech and language disorders are diagnosed with developmental aphasia, as this is the only diagnosis that allows children to obtain an individual school program and therapeutic support at school. In contrast, children with milder developmental speech and language disorder are diagnosed with SLI. Typically, these types of diagnoses are issued by speech and language pathologists working in state counseling centers. In the current study, the DLD group included children with a diagnosis of developmental aphasia and SLI. In this study, which was designed as a pilot study, recruitment to the DLD group was based on documents provided by parents, and it was not possible to verify the profile of speech and language disorders of a particular child. Children's diagnoses did not contain a common formula and did not always present the child's level of functioning in all aspects of speech and language development.

Children with DLD were recruited by speech and language therapists and via Facebook posts on support groups for parents of children with severe speech and language development deficits. These children were tested in the presence of their parents at the child's home or in other environments (i.e., offices, rooms at universities or schools) while protecting the child's privacy. TD children were recruited at schools and kindergartens, and their tests were performed on site without parents, also in environments that guaranteed privacy. Parental and child assent were obtained prior to participation. The ethics committee of the Psychology Department at SWPS University of Social Sciences and Humanities in Warsaw, Poland, approved the study. All research test procedures were conducted by the first author.

Procedure and Stimuli

Nonword Repetition Tests

Nonword repetition (NWR) tests are sensitive markers for DLD and RD, as children with DLD obtain poorer results on these compared to TD children and younger children with matching language abilities (Archibald & Gathercole, 2006; Dispaldro et al., 2013; Graf Estes et al., 2007; le Clercq et al., 2017). NWR tests assess the interactions between phonological representations, the auditory system, articulation, vocabulary, and literacy skills (Archibald & Gathercole, 2006). Nonwords are a series of phonemes that are not identical to any word in a given language but resemble them from a structural point of view. Generally, the more a person knows the typical word structure in a given language, the easier it is for them to repeat artificially coined words.

In this study, a Polish NWR was used (Szewczyk et al., 2015). In this case, 27 oral stimuli (two-, three-, and four-syllable nonwords) were presented one after the other, and a child was asked to repeat them. The child scored 1 point for a correctly repeated nonword, and 0 points for no answer or an incorrect repetition. The child could obtain a total of 27 points (raw score). These raw scores were later converted into a stanine score adequate for a given age.

PR Tasks

To test the degree of uninhibited PRs, tasks were applied based on Goddard Blythe's (2012, 2018) proposal. In this case, the child could score 0–4 points in each task, and a higher result indicated a stronger reflex reaction. The total number of points obtained in the examination of six reflexes created an additional cumulative variable: the NMI (ranging from 0 to 24 points).

The TLR task. The researcher asked the participants to maintain a still position by standing straight, feet together, and arms by their sides. Participants were then asked to tilt their heads slowly backward as if to look at the ceiling and to close their eyes and hold this position for 10 s. Then, participants were asked to tilt their heads slowly forward as low as possible as if to look at their toes and to maintain this position for 10 s. The participants repeated this whole sequence 3 times. The researcher observed the movements of the body. For example, swaying, loss of balance, opening of the eyes, changes in muscle tone at the back of the knees, and movements of the toes and arms. Scoring for the TLR was as follows:

1. 0 = no reaction;
2. 1 = minimal changes in balance and muscle tone as a result of changes in head position;
3. 2 = imbalance during the test and/or change in muscle tone;
4. 3 = the child is close to losing balance and/or there has been a significant change in muscle tone, and/or confusion after completing the task, and/or tendency to open eyes; and
5. 4 = loss of balance and/or pronounced muscle tone adjustments to stabilize balance, which may be accompanied by dizziness or nausea.

The ATNR task. The researcher asked the participants to maintain a still quadruped position with knees under the hips, hands under the shoulders, and head in line with the back. The researcher knelt in front of the participants and slowly turned their heads to the side and stopped in the end positions for 5 s. The whole sequence was repeated 3 times. The researcher observed the movements of the arms, shoulders, and hips. Scoring for the ATNR was as follows:

1. 0 = no opposite arm, shoulder, or hip movement;
2. 1 = slight deflection of the opposite arm or movement of the shoulder or hip;
3. 2 = definite arm deflection or shoulder or hip movement;
4. 3 = 45° deflection of the opposite arm with or without shoulder or hip movement; and
5. 4 = falling on the side of the opposite arm due to head rotation; hip movement may also occur.

STNR in flexion and STNR in extension tasks. The researcher asked the participants to maintain a still, quadruped position with knees under hips, hands under shoulders, and head in line with the back. The researcher knelt in front of the participants and asked them to lower their head slowly, as if to look between their legs without moving other parts of their body. The participants were asked to hold this position for 5 s. Then, the participants were asked to lift their head slowly, as if to look at the ceiling and to maintain this position for 5 s. The whole sequence of movements was repeated 3 times. The researcher observed the movements of the arms, hands, elbows, and back while lowering the participant's head (the STNR in flexion [STNR-F]) or lifting the participant's head (the STNR in extension [STNR-E]). Scoring for the STNR-F was as follows:

1. 0 = no reaction;
2. 1 = trembling of one or both arms in response to lowering the head;
3. 2 = slight deflection at the elbows in response to lowering the head;
4. 3 = strong shoulder flexion in response to lowering the head and/or raising the feet; and
5. 4 = falling as a result of bending the arms when the head is lowered.

In contrast, scoring for the STNR-E was as follows:

1. 0 = no reaction;
2. 1 = slight movement in the hips (lower body flexion) in response to lifting the head;
3. 2 = noticeable movement in the hips in response to lifting the head;
4. 3 = strong hip movement in response to lifting the head; and
5. 4 = lowering the buttocks to the heels to the "sitting cat" position in response to lifting the head.

The Galant reflex task. The researcher asked the participants to maintain a still quadruped position with the skin surface of the back (from the shoulder blade) uncovered. The researcher ran a thin wooden stick down the spine (at a distance of 1.25 cm), first to one side of the spine and then to the other side. The whole sequence was repeated 3 times. The researcher observed the movements of the hips toward the stimulated part of the body. Scoring for the Galant reflex was as follows:

1. 0 = no reaction;
2. 1 = on the stimulated side, outward hip movement occurred at an angle of 15°, with possible hypersensitivity or tickling sensation;
3. 2 = on the stimulated side, outward hip movement occurred at an angle of 30°, with possible hypersensitivity or tickling;

4. 3 = on the stimulated side, outward hip movement occurred at an angle of 45°, with possible sensitivity or tickling; and
5. 4 = on the stimulated side, outward hip movement occurred at an angle over 45°, thereby affecting the child's balance, with possible sensitivity or tickling.

The Moro reflex task. The researcher asked the participants to maintain a still standing position with their feet together, head slightly tilted backward, elbows bent and abducted to 45°, wrists and fingers relaxed, and eyes closed. The researcher stood behind with hands on participants' shoulders. Participants were asked to tense their body, to lean backward on the researcher's hands, and to stand on their heels. Participants were assured by the researcher that they will be held, were informed of what was going to happen next, and were asked not to change their body position during the task. When participants were standing on their heels and had shifted their weight to the researcher's hands, the researcher moved their hands away and allowed the participants to fall backward from 10° to a maximum of 30° and then firmly caught the participants to stop them from falling further. The researcher observed the stability of the shoulder position, the emotional state, change in face color (i.e., pale or flushed), potential unwillingness to lean backward or blocking it (e.g., withdrawing the feet, compensatory head movements, fear, opening of the eyes), and change in behavior after the test in comparison to behavior before the test (i.e., calming down and withdrawal or agitation). As the task was likely to evoke an intense emotional reaction, it was conducted last. Scoring for the Moro reflex task was as follows:

1. 0 = no reaction, the arms remain in the starting position;
2. 1 = slight movement of the arms outside and/or redness of the skin;
3. 2 = a definite partial abduction of the arms and an intake of breath and/or little reluctance to take part in the test, difficulty falling backward;
4. 3 = 75% abduction of the arms and/or the participant is "shaken" by the test procedure and/or holding his/her breath, skin redness or pallor; and
5. 4 = full abduction of the arms and/or very significant irritation during the test procedure, possible screaming, significant resistance to the test, or anxiety.

Statistical Analysis

The statistical analysis was performed using SPSS Version 24. Descriptive statistics were computed for all variables: NWR, NMI, Moro reflex, TLR, ATNR, STNR-F, STNR-E, and Galant reflex. The analyses were carried out across two test groups: TD and DLD. To examine if the obtained distributions differed from the theoretical normal distribution, Kolmogorov–Smirnov tests were conducted. Correlation analysis was performed to determine the associations among the variables. Specifically, Spearman's rho nonparametric measure of rank correlation was used, as it is suitable for use with nonnormally distributed variables. When comparing the TD and DLD groups, 2 (sex: male × female) × 2 (group: TD × DLD) analysis of variance (ANOVA) tests were run. Main effects and interactions were assessed. The significance level was set at $p < .05$. Bonferroni corrections were used in all analyses and for main and interaction effects.

Results

Statistical Description

Data analysis began with the calculation of descriptive statistics of phonological processing (NWR), NMI, and the six PRs: Moro reflex, TLR, ATNR, STNR-F, STNR-E, and Galant reflex. The whole spectrum of descriptive statistics was calculated: range (min–max), mean, standard deviation, skewness, and kurtosis (see Table 1).

Additionally, Kolmogorov–Smirnov tests were conducted to determine if the obtained distributions differed from theoretical normal distributions. The obtained statistical values showed that, in all cases, the variables significantly deviated from the normal distribution. Kurtosis statistics calculated for NWR and the Moro reflex index showed a marked platykurtosis, indicating a large dispersion of results in relation to the mean. However, no marked skewness was observed.

Co-Occurrence of Reflexes

To determine the associations between the examined variables, a correlation analysis was conducted (see Table 2). Nonparametric Spearman's rho tests were applied, as our variables were not normally distributed. The correlation matrix revealed that all indicators were interlinked. Specifically, the obtained coefficients showed that increases in NWR scores were associated with moderate decreases in NMI, STNR-F, ATNR, STNR-E, TLR, and Moro reflex and only slight decreases in the Galant reflex.

Table 1. Descriptive statistics for nonword repetition (NWR), neuromotor immaturity (NMI), Moro reflex, tonic labyrinthine reflex (TLR), asymmetrical tonic neck reflex (ATNR), symmetrical tonic neck reflex in flexion (STNR-F) and in extension (STNR-E), and Galant reflex (N = 174).

Variable	R	*M*	*SD*	Sk	Kurt	*D*
NWR	1–9	4.40	2.47	.06	−1.15	.13*
NMI	0–20	10.16	5.00	.12	−0.87	.09*
Moro reflex	0–4	2.22	1.43	−.05	−1.35	.19*
TLR	0–4	1.86	1.08	.34	−0.58	.21*
ATNR	0–4	1.87	1.04	.04	−0.87	.21*
STNR-F	0–4	1.69	1.01	−.07	−0.59	.23*
STNR-E	0–4	1.42	1.00	.60	0.10	.25*
Galant reflex	0–4	1.09	1.28	.95	−0.33	.25*

Note. R = range; Sk = skewness; Kurt = kurtosis; *D* = average deviation.

*p < .01.

Table 2. Correlations of nonword repetition (NWR), neuromotor immaturity (NMI), Moro reflex, tonic labyrinthine reflex (TLR), asymmetrical tonic neck reflex (ATNR), symmetrical tonic neck reflex in flexion (STNR-F) and in extension (STNR-E), and Galant reflex (N = 174).

Variable	1	2	3	4	5	6	7	8
1 NWR	—							
2 NMI	−.44*	—						
3 Moro reflex	−.31*	.71*	—					
4 TLR	−.33*	.79*	.46*	—				
5 ATNR	−.38*	.81*	.55*	.61*	—			
6 STNR-F	−.38*	.76*	.39*	.55*	.59*	—		
7 STNR-E	−.34*	.77*	.39*	.62*	.55*	.63*	—	
8 Galant reflex	−.25*	.60*	.23*	.35*	.35*	.32*	.39*	—

*p < .01.

Apart from the described negative correlations, all other indicators were positively correlated with one another. The strongest positive correlations were observed between NMI and all reflexes, and the weakest correlation coefficients were found between Galant reflex intensity and the Moro reflex, TLR, ATNR, STNR-F, and STNR-E indicators.

DLD and Sex Versus NWR Score and PRs

To assess whether participants in the TD and DLD groups differed in terms of individual indicators (i.e., NWR, NMI, Moro reflex, TLR, ATNR, STNR-F, STNR-E, and Galant reflex), a series of 2 × 2 ANOVAs were calculated, as described below and illustrated in Table 3.

NWR Test

The ANOVA comparing NWR scores in the control (TD) group and the DLD group showed a significant main effect of group (see Table 4). That is, children in the TD group had higher NWR scores compared to the DLD group (p < .001). However, there was no significant main effect or significant interaction involving sex.

NMI

In the analysis of intergroup differences in NMI scores (see Table 4), we found no significant main effect or interaction involving sex. However, children in the TD group had significantly lower scores than the DLD group (p < .001).

Moro Reflex

An identical result was observed in the Moro reflex intensity measure (see Table 5), where the reflex level in children in the TD group was lower than the DLD group (p < .001). There was no significant main effect of sex or interaction of both factors.

TLR

The next analysis concerned TLR (see Table 5) and showed a significant main effect of group, where the reflex level in the TD group was lower than in the DLD group (p < .001). In this case, a significant interaction was observed, as boys in the DLD group scored significantly higher than girls in the DLD group (trending at p = .098) and boys in the TD group (p < .001). Moreover, girls in the DLD group had significantly higher scores than girls in the TD group (p = .046). However, there was no significant main effect of sex.

ATNR

There was a significant main effect of group (see Table 6), where ATNR level in children in the TD group was lower than those in the DLD group (p < .001). An additional analysis revealed a significant interaction of sex and speech and language disorders in ATNR. Specifically, boys in the TD group had lower levels of ATNR compared

Table 3. Developmental language disorder (DLD) and sex versus all indicators: nonword repetition (NWR), neuromotor immaturity (NMI), Moro reflex, tonic labyrinthine reflex (TLR), asymmetrical tonic neck reflex (ATNR), symmetrical tonic neck reflex in flexion (STNR-F) and in extension (STNR-E), and Galant reflex.

Variable	Main group effect	Main sex effect	Interaction effect
NWR	TD > DLD**	*ns*	*ns*
NMI	DLD > TD**	*ns*	*ns*
Moro reflex	DLD > TD**	*ns*	*ns*
TLR	DLD > TD**	*ns*	DLD boys > DLD girls*** DLD boys > TD boys** DLD girls > TD girls*
ATNR	DLD > TD**	*ns*	DLD boys > TD boys** TD girls > TD boys* DLD girls > TD girls***
STNR-F	DLD > TD**	*ns*	DLD boys > TD boys**
STNR-E	DLD > TD**	*ns*	*ns*
Galant reflex	DLD > TD**	*ns*	*ns*

Note. TD = typical development; *ns* = not significant.
*p < .05. **p < .01. ***p < .099.

Table 4. Developmental language disorder (DLD) and Sex versus nonword repetition (NWR) and neuromotor immaturity (NMI) scores.

Variable			*M*	*SD*	*F*	*p*	η^2	Post hoc
NWR	A	Boys	4.30	2.51	0.78	.380	.002	*ns*
	B	Girls	4.69	2.32				
	I	DLD	2.27	1.61	161.35	< .001	.486	I < II
	II	TD	6.01	1.64				
	I.A	DLD boys	2.21	1.68	0.00	.987	.000	*ns*
	I.B	DLD girls	2.47	1.38				
	II.A	TD boys	5.95	1.70				
	II.B	TD girls	6.20	1.44				
NMI	A	Boys	10.11	5.09	0.12	.729	.001	*ns*
	B	Girls	10.31	4.76				
	I	DLD	13.51	4.47	55.11	< .001	.243	I > II
	II	TD	7.63	3.75				
	I.A	DLD boys	13.64	4.49	1.29	.258	.006	*ns*
	I.B	DLD girls	13.06	4.51				
	II.A	TD boys	7.35	3.64				
	II.B	TD girls	8.44	4.03				

Note. Post hoc comparisons were performed using Bonferroni test. TD = typically developing; *ns* = not significant.

to boys with DLD ($p < .001$) and girls in the TD group ($p = .031$). In addition, girls in the DLD group had higher mean values compared to girls in the TD group (trending at $p = .057$). However, there was no significant main effect of sex.

STNR-F

To examine the influence of speech and language disorders and sex on STNR-F, an additional two-way ANOVA was performed (see Table 7), resulting in a significant main effect of group and a significant interaction. The STNR-F level in children in the TD group was lower than the DLD group ($p < .001$). Paired comparison tests indicated that boys in the DLD group had a stronger STNR-F than boys in the TD group ($p < .001$). However, there was no significant main effect of sex.

STNR-E

An ANOVA comparing STNR-E scores (see Table 7) showed a significant main effect of group, but no significant interaction. More precisely, the DLD group had higher STNR-E scores than the TD group ($p < .001$). However, there was no significant main effect of sex.

Galant Reflex

The last ANOVA compared Galant reflex scores (see Table 6). As in the previous case, there was no significant interaction between sex and speech and language disorder and no significant main effect of sex; however, the DLD

Table 5. Developmental language disorder (DLD) and sex versus Moro reflex and tonic labyrinthine reflex (TLR).

Bonferroni test			*M*	*SD*	*F*	*p*	η^2	Post hoc
Moro reflex	A	Boys	2.20	1.45	0.39	.536	.002	*ns*
	B	Girls	2.31	1.35				
	I	DLD	2.83	1.30	19.50	< .001	.103	I > II
	II	TD	1.77	1.35				
	I.A	DLD boys	2.79	1.32	0.00	.996	< .001	*ns*
	I.B	DLD girls	2.94	1.25				
	II.A	TD boys	1.73	1.39				
	II.B	TD girls	1.88	1.27				
TLR	A	Boys	1.89	1.13	0.74	.391	.004	*ns*
	B	Girls	1.76	0.91				
	I	DLD	2.45	1.00	27.11	< .001	.135	I > II
	II	TD	1.41	0.90				
	I.A	DLD boys	2.55	0.99	2.87	.092	.014	I.A > I.B
	I.B	DLD girls	2.12	0.99				I.A > II.A
	II.A	TD boys	1.38	0.95				I.B > II.B
	II.B	TD girls	1.52	0.77				

Note. Post hoc comparisons were performed using Scheffé–Bonferroni test. TD = typical development; *ns* = not significant.

Table 6. Developmental language disorder (DLD) and sex versus asymmetrical tonic neck reflex (ATNR) and Galant reflex.

Variable			*M*	*SD*	*F*	*p*	η^2	Post hoc
ATNR	A	Boys	1.83	1.06	1.24	.268	.006	*ns*
	B	Girls	2.02	0.97				
	I	DLD	2.43	0.99	25.42	< .001	.127	I > II
	II	TD	1.45	0.87				
	I.A	DLD boys	2.45	1.01	2.86	.093	.014	II.A < II.B
	I.B	DLD girls	2.35	0.93				I.A > II.A
	II.A	TD boys	1.34	0.82				I.B > II.B
	II.B	TD girls	1.80	0.96				
Galant reflex	A	Boys	1.09	1.27	0.04	.835	.000	*ns*
	B	Girls	1.10	1.30				
	I	DLD	1.64	1.44	20.99	< .001	.110	I > II
	II	TD	0.68	0.96				
	I.A	DLD boys	1.62	1.46	0.04	.851	.000	*ns*
	I.B	DLD girls	1.71	1.40				
	II.A	TD boys	0.68	0.92				
	II.B	TD girls	0.68	1.07				

Note. Post hoc comparisons were performed using Bonferroni test. TD = typical development; *ns* = not significant.

group had higher Galant reflex scores than the TD group ($p < .001$).

Discussion

Early diagnosis and treatment of children with DLD is of utmost importance. For instance, research indicates that, if delays in language development are not reduced by early school age, attention-deficit disorders and social difficulties occur more frequently (Snowling et al., 2006). A similar discovery was made by Marschik et al. (2007), who found that vocabulary competencies at 24 months of age were correlated with social competencies. According to Gaines and Missiuna (2007), significant coordination deficits in small children with DLD are unfortunately not easily noticeable until preschool age when motor deficits start to influence children's self-service activities and educational tasks. We believe a confirmed relationship between speech and language development and the process of inhibiting PRs will be useful for the early detection of DLD in children, as abnormal motor development is already observable in the early months of life. Thus, the presence of PRs in the second year of life should already be a clear indication that a child requires additional support.

Since Bishop and Edmundson (1987) noticed that children with DLD have motor problems, there has been increasing evidence of all kinds of motor weaknesses in this group of children (Powell & Bishop, 1992; Ullman & Pierpont, 2005; Vuolo et al., 2017; Zelaznik & Goffman, 2010). We believe that PRs may be the basic motor function

Table 7. Developmental language disorder (DLD) and sex versus symmetrical tonic neck reflex in flexion (STNR-F) and in extension (STNR-E).

Variable			*M*	*SD*	*F*	*p*	η^2	Post hoc
STNR-F	A	Boys	1.68	1.01	0.00	.996	< .001	*ns*
	B	Girls	1.71	1.02				
	I	DLD	2.15	0.95	14.23	< .001	.075	I > II
	II	TD	1.34	0.91				
	I.A	DLD boys	2.22	0.92	4.28	.040	.023	I.A > II.A
	I.B	DLD girls	1.88	1.05				
	II.A	TD boys	1.26	0.86				
	II.B	TD girls	1.60	1.00				
STNR-E	A	Boys	1.42	0.97	0.02	.883	.000	*ns*
	B	Girls	1.40	1.11				
	I	DLD	2.01	0.98	46.38	< .001	.214	I > II
	II	TD	0.97	0.76				
	I.A	DLD boys	2.00	0.92	0.05	.818	.000	*ns*
	I.B	DLD girls	2.06	1.20				
	II.A	TD boys	0.97	0.76				
	II.B	TD girls	0.96	0.79				

Note. Post hoc comparisons were performed using Bonferroni test. TD = typical development; *ns* = not significant.

that link previous findings on DLD and motor development. Our results showed that greater NMI and higher levels of each individual PR were associated with lower NWR scores. This suggests that lower levels of language skills are linked to more uninhibited PRs and greater NMI. This finding was confirmed for moderate levels of most reflexes, specifically the Moro reflex, STNR-F, STNR-E, ATNR, and TLR, and for low levels of the Galant reflex. The relationship between NWR and NMI scores appeared to be stronger than the relationship between NWR scores and the scores of each reflex individually. This finding suggests that a set of uninhibited reflexes may be more significant for speech and language development than single abnormal reflexes.

Children in the TD group had lower scores on the scales for Moro reflex, STNR-E, and Galant reflex, as compared to children with DLD. According to Goddard Blythe (2018), the uninhibited Moro reflex and related acoustic stapedius reflex can lead to acoustic hypersensitivity. The study of Ralli et al. (2018) has indicated that children with hyperacusis (hypersensitivity to sound) struggle with lexical access and produce shorter sentences, which, according to Leonard (2014), are two common features of DLD. Likewise, the STNR-E reflex may play an important role in the functioning of the cerebellum (Goddard Blythe, 2017), which is essential for areas that are reported as weak in children with DLD: balance (Estil et al., 2003; Fernell et al., 2002; Müürsepp et al., 2011; Powell & Bishop, 1992), motor coordination (Cheng et al., 2009; Hill, 1998, 2001), bilateral coordination (Bishop, 1990; Estil et al., 2003; Vukovic et al., 2010; Vuolo et al., 2017), and language processing (Drljan &Vuković, 2019). Similarly, the Galant reflex is linked to auditory processing skills (Goddard Blythe, 2018), which also may be impacted in some children with DLD (Ferguson et al., 2011; Richards & Goswami, 2015; Victorino & Schwartz, 2015). Although previous researchers have found that children with DLD display hyperreflexia compared to their TD peers (Trauner et al., 2000), this study is the first to identify specific PRs that remain uninhibited in children with DLD compared to their TD peers, which may contribute to their motor and language deficits.

Regarding other reflexes, differences between girls and boys were observed. For instance, TD boys presented with lower levels of STNR-F, TLR, and ATNR than boys with DLD, whereas TD girls differed from girls with DLD only in TLR and ATNR. Additionally, there were sex differences observed across the levels of two reflexes (i.e., TLR and ATNR). More precisely, TLR was higher in the group of boys with DLD than in the group of girls with DLD. An opposite trend appeared in the case of ATNR in the TD children, that is, the girls in this group had a higher level of the reflex than boys. We were surprised by such differences in the results of boys' and girls' reflex levels, as we expected some reflexes to be higher in boys than in girls. However, this was confirmed only in relation to one reflex (i.e., TLR) in the group of children with DLD and the exact opposite tendency was observed in relation to one reflex (i.e., ATNR) in the TD children, which is contrary to the findings of McPhillips and Sheehy (2004). However, it is possible that this trend is associated with more frequent sports activities for boys than girls (Deaner et al., 2016), subsequently impacting the development of reflexes in TD children. Nevertheless, this issue requires further research.

As expected, significant differences were observed in the NWR test, which is not only an indicator of speech motor function but also displays a broader perspective in terms of phonology, hearing, vocabulary, and literacy skills. That is, children in the TD group achieved higher scores than children with DLD. Our analyses showed that girls and boys did not differ in any group in terms of NWR test scores. Nevertheless, the sample in the current study was clearly masculinized (76% boys and 24% girls), which is consistent with the assumption that DLD is more likely to occur in boys than in girls (Broomfield & Dodd, 2004; Tomblin et al., 1997). Our study has confirmed the previous results of the Matuszkiewicz (2016) study that NWR was negatively correlated with NMI. This means that the higher the level of uninhibited PRs, the lower the NWR scores. This result is especially important for children with DLD. Low NWR scores are associated with many aspects of speech and language development: phonological working memory (Gathercole et al., 1994), vocabulary (Verhagen et al., 2019), auditory processing (Fox et al., 2012), and lexical and sublexical knowledge (Archibald & Gathercole, 2006; Jones & Witherstone, 2011).

In addition, our study indicated a relationship between DLD and motor deficits in the form of uninhibited PRs. This result confirms what has been found in numerous previous studies concerning children with DLD and their deficits in various motor tasks. In the Rintala et al. (1998) study, 71% of children with DLD met the criteria for DCD, compared to only 5% of TD children. In addition, other studies have compared children with DLD divided into two subgroups: those with expressive language disorder and those with receptive language disorder. These studies (Noterdaeme et al., 2002; Visscher et al., 2010) have shown differences in motor development between the two subgroups of children with DLD and TD children. Greater motor deficits were observed in children with expressive DLD than in those with receptive DLD. Although both subgroups were mostly similar in the area of balance, they differed in terms of their ability to perform complex motor tasks.

According to Ross et al. (2018), only expressive language can be predicted at a statistically significant level, regardless of the category of motor skill performance. Importantly, receptive language is different in TD children only in cases of moderate and severe motor delays. Interestingly, the results of Fisher's (2017) study suggest that speech comprehension in young children may be a better predictor of scores of language expression than speech production at an early age. Therefore, we may conclude that the relationship between delays in motor and speech and language development is only significant in cases of more serious motor difficulties. Thus, a deeper analysis of the phenomenon of uninhibited reflexes in children with DLD is planned for a future study, covering a wide range of children's linguistic competences (i.e., expression and reception).

Nevertheless, we believe that uninhibited PRs can be important for speech and language development. In fact, our study confirmed that, in the group of children with DLD, the level of these reflexes was higher than in the TD group. Thus, we would like to further investigate whether a causal relation is present, as we suspect that tonic reflexes (i.e., TLR, ATLR, and STNR) may be associated with cerebellar functioning, thereby affecting the development and functioning of cognitive skills (see Starowicz-Filip et al., 2013), including language processing. Studies comparing children with DLD and TD children (Victorino & Schwartz, 2015) indicate that children with DLD present difficulties with auditory attention control and inhibition of reactions to distracting stimuli. According to Goddard Blythe (2018), increased sound sensitivity often co-occurs in children with a persistent Moro reflex, which may be the result of a prolonged period of activity, thereby preventing the acoustic stapedius reflex—which provides adequate protection against noise—from developing completely. Although our study revealed a relationship between the Moro reflex and language skills, future studies should also include auditory processing. Nevertheless, Goddard Blythe's (2018) study may help explain why the Galant reflex appeared to be least related to speech and language development impairment, although there may still be a link between this reflex and middle ear infections.

Research indicates that children with DLD present with less stable patterns of articulatory movements than TD children, as described by Brumbach and Goffman (2014). In addition, frequently observed motor deficits in children with DLD are correlated with speech motor skills, yet only fine motor skills are related to articulatory variability. Although there were correlations between gross motor, fine motor, and speech motor skills, the NWR test, which was used as a highly sensitive marker of DLD, was unrelated to speech motor skills. Thus, the interaction between motor and language development seems to be more complex. This is why we will be considering articulation in our future study as well.

The question of the relationship between speech and language, and motor development seems so vast and complex that, currently, very little is known in this area. Thus, further studies need to be carried out with a new approach that could lead to finding effective therapies for children with DLD. On the one hand, this proposed research will be based on numerous studies conducted in the past, which found that children with DLD demonstrated NMI. However, on the other hand, this research will be founded on studies indicating that movement programs impact PRs and are effective as reading and writing therapies, which are two skills that are significantly correlated with language skills. Such an approach to language difficulties is innovative because it may offer an opportunity to earlier diagnoses of DLD and earlier interventions for children with DLD and to implement reflex movement therapy to improve the language functioning of a child.

Limitations

One limitation of our study is that the data available for this study do not indicate a causal relation between DLD and basic motor skills (e.g., PRs). Another limitation is the absence of standardized test batteries to measure PRs. Although our findings provide evidence that uninhibited PRs may be a significant factor in children with DLD, this group may be heterogeneous in terms of language. A major limitation in this study is the lack of clear diagnostic criteria and language profiles for the participants. Thus, it is necessary to conduct further research on levels of PR in children with DLD, paying particular attention to all language functions, both expressive and receptive.

This study was designed as a pilot study. Its aim was to determine if children with DLD presented with increased levels of uninhibited PRs that might be indicative of potential NMI. The Polish system for diagnosing children with DLD is not perfect, so it was not possible to separate subgroups of the disorder due to specific difficulties with the current diagnostic system. Thus, to obtain a profile of children's language development, it will be necessary to conduct broader language testing of all children and not just the NWR test, which we used. Thus, in the future, we plan to use a full battery of speech and language tests. Despite these limitations, we believe our findings are a unique and an innovative addition to understanding the development of children with DLD. Our study has yielded valuable results regarding the relationship between DLD and motor development at the most basic level. Confirmation of these findings in a future study with a thorough analysis of all language functions will bring us closer to a deeper understanding of the DLD phenomenon. We also hope that this will help diagnose and treat children with this disorder at an early stage.

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