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THE MORO REFLEX IN PREDICTING DEVELOPMENT OF ANXIETY IN YOUNG CHILDREN

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SUMMARY

Background: Although previous studies have suggested a link between uninhibited Moro reflexes (MR) and anxiety, empirical evidence remains limited. This study investigated the relationship between uninhibited MR and anxiety in children. A total of 372 Polish children of preschool and school age (Mage = 9.6 years; 60% boys, 40% girls) were assessed for the presence and severity of MR. Based on parental reports, children were categorized into anxiety (n = 182) and non-anxiety (n = 192) groups.

Material/ Methods: A total of 374 children (225 boys and 149 girls, M_{age} = 9.6 years, range: 4.0–17.9) participated in this study. The anxiety and non-anxiety groups included 182 (60% boys, 40% girls) and 192 (60% boys, 40% girls) children, respectively. The participants were divided into four equal age groups: youngest children (age ≤ 7.6 years), younger middle children (age 7.7–9.1 years), older middle children (age 9.2–10.8), and oldest children (age ≥ 10.9). MR was evaluated using two tasks: the falling and the tilting task. Reflex intensity was scored and compared across sex and anxiety groups. Statistical analyses examined the association between MR scores and anxiety prevalence.

Results: MR scores were significantly higher – indicating reduced subcortical inhibition – in girls compared to boys, and in the anxiety group compared to the non-anxiety group. Boys without anxiety exhibited lower MR scores than boys with anxiety (p = .003) and girls without anxiety (p = .061). Significant differences in MR scores between anxiety and non-anxiety groups were observed only among the youngest (p < .001) and oldest children (p = .027). Notably, boys with a completely uninhibited MR were nearly three times more likely to be classified as anxious.

Conclusions: This study provides the first empirical evidence of a positive association between MR and anxiety in children. The relationship was particularly pronounced in cases of completely uninhibited MR, suggesting a potential neurodevelopmental marker for anxiety risk.

Key words: Moro reflex, anxiety, child development, primitive reflex

INTRODUCTION

According to Thelèn and Smith (1994), newborn behaviors are largely reflexive with phylogenetically old patterns, one of which is the Moro reflex (MR). At birth, the cerebral cortex is histologically immature and unmyelinated. As the cortex matures during the first year of postnatal life, it gradually inhibits subcortical output and increasingly controls the neuromuscular system.

Increasing evidence indicates that symptoms of neuromotor immaturity develop in children with developmental disorders such as autism spectrum disorder (ASD) (Akbuğa&Eliöz, 2021; Brandes, 2015; Chinello et al., 2018; Jeżewska-Krasnodębska&Krasnodębski, 2018), attention-deficit/hyperactivity disorder (ADHD) (Brandes, 2015; Konicarova& Bob, 2012; Taylor et al., 2004), reading disorders (González et al., 2008; McPhillips & Jordan-Black, 2007), visual processing disorder (VPD) (Hinkley & Smith, 2011), and developmental language disorder (DLD) (Matuszkiewicz & Gałkowski, 2021). Neuromotor immaturity manifests as a set of uninhibited primitive reflexes (PRs). PRs are automated, complex movement patterns mediated by the brainstem which emerge and develop in the uterus. PRs are typically present in newborns during the first 6 months of life (Capute et al., 1982). Until recently, it has been thought that PRs are a symptom of brain pathology that occurs only in the presence of clear lesions of the central nervous system (CNS) (Borkowska, 2001). However, increasing evidence indicates that this type of neuromotor immaturity occurs in the general population of preschool and school-age children (Gieysztor et al., 2018; Gieysztor et al., 2017; Grzywniak, 2016; Matuszkiewicz & Gałkowski, 2021). PRs can also be uninhibited in both children and adults who suffer from anxiety, panic disorder, phobias, and depression (Blythe & McGlown, 1979). They can also reappear in the presence of brain damage (Capute et al., 1984) or brain diseases, particularly those affecting the frontal lobes (Schott &Rossor, 2003).

MR examination is a component of newborn neurological assessments (Salandy et al., 2019). Unlike simple reflexes that involve individual parts of the body, MR is a complex reaction that integrates a set of neurological movements. Hence, it may be an early indicator of brain damage and act as a reliable guide for early diagnosis of neurodevelopmental disorders. Taken together, this may accelerate the initiation of rehabilitation and help in preventing long-term complications (Ince et al., 2019).

The initial or newborn phase is a characteristic MR pattern in an early-stage infant (McGraw, 1937). It involves a bilateral extension and abduction of the upper limbs, an extension of the spine often involving a retraction of the head, a rolling of the body slightly to one side, an extension and swinging of fingers but a flexion of the index finger and the thumb, and a flexion of the lower limbs followed by a large bilateral extension. During this phase, a baby usually cries intensely. According to Goldstein's theory (1938), the flexion pattern is the return of the arms to the natural position of the infant's body at the earliest stage of life. Small for gestational age full-term infants have shown weaker arm flexions than

normal weight term infants (Fredrickson & Brown, 1980). In the second or third month, the second or transitional phase of the behavior pattern appears. All movements are reduced, and lower limb movements are withdrawn completely. Crying is less frequent and less intense, and sometimes the baby makes a crying face but does not cry. Blinking of the eyelids occurs, and sometimes there is a jerk of the head or upper body. The first phase with an outward movement of the arms occurs regardless of the child's age, while the second phase with inward movement occurs in the neonatal period (0–4 days and 6 weeks) but no longer occurs at 12 weeks of age (Parmelee, 1964).

The MR in infants is considered abnormal when it is absent or weak, exaggerated during the period in which it should be active, or persists after the age at which it is normally inhibited (Futagi et al., 2012). The reaction pattern, latency, and duration of the MR are largely dependent on the condition of the infant (Rönnqvist, 1995). The most pronounced response occurs when the infant is calm but awake, as it is difficult to get a full reflex response when the baby is sleeping or crying.

A weak or absent MR occurs in apathetic or depressed newborns with hypotonia, who move less than normal babies (Prechtl, 1965). The absence of the MR was also observed in a neonate in a serious condition caused by hand, foot, and mouth disease with serious complications such as brainstem encephalitis, pulmonary oedema, fever, lethargy, and dyspnea (Guo et al., 2014). The lack of an MR during the first 6 days of life in children with hypoxic-ischemic encephalopathy is a predictor of cerebral palsy (CP), epilepsy, and intellectual disability (Ishikawa et al., 1987). The extant literature (Futagi et al., 2012; Hamer &Hadders-Algra, 2016) indicates that an abnormal MR in the neonatal and early infancy periods is an indicator of disorders such as intracranial hemorrhage, brain malformations, birth trauma, severe birth asphyxia, infection, low muscle tone, and spastic CP.

An examinationof the MR pattern in children with postnatal neurological abnormalities demonstrated that the reflex response may differ depending on the cause (Heyworth & Sanford, 1933). Infants with cerebral edema born after a long, difficult labor or by forceps delivery lack the MR on the first day. The MR gradually returns during the following 4 days. Infants with cerebral hemorrhage have a positive MR within the first 12 hours of life; however, the MR disappears and returns when the infant's condition has improved, but no earlier than day 6. In infants with spastic CP, the MR does not appear until 5–7 months and lasts up to 11 months of age. This delayed onset is explained by spontaneous maturation of the CNS or physiotherapeutic interventions (Zafeiriou, 2004). In high-risk infants, both the persistence of the MR and its absence during the first 4 months of life are predictors of CP (Garfinkle et al., 2020).

An exaggerated MR occurs in infants with severe bilateral intrauterine disorders such as hydranencephaly (Futagi et al., 2012; Hamer & Hadders-Algra, 2016). A hyperactive MR is common in infants of mothers addicted to substances such as heroin (Chasnoff & Burns, 1984), opioids (Jones et al., 2010), cocaine (Nayeri et al., 2015), tobacco (Kiseleva et al., 2016), or volatile substances

(Tenenbein et al., 1996). Additionally, in infants with neonatal narcotic withdrawal, a hyperactive MR is associated with a delayed inhibition pattern of this reflex, a small head circumference, and difficulty in maintaining state control (Chasnoff & Burns, 1984). Pucher et al. (1987) suspect that the MR is hyperactive in infants at risk of sudden infant death syndrome.

A long MR latency interval (> 0.49 s) is a valuable clinical sign to screen for neurological impairment in hypoxic ischemic encephalopathy (Sagaria& Rao, 2019). Long latency may also indicate severe nervous system pathology (Bijesh et al., 2013). The pronounced asymmetry of the MR (the absence of the reflex on one side) indicates either motor paralysis or an injury to that side of the body such as Erb's palsy (Goddard Blythe, 2017), a fractured clavicle or humerus, or injury to the shoulder joint (Rönnqvist, 1995). A slight functional asymmetry of the MR (i.e., a faster response in one arm) is the correct normal response (Rönnqvist, 1995).

The procedureof the delivery and gestational age (GA) at delivery also affects the MR (Forslund & Bjerre, 1983). Infants born via caesarean section have a stronger MR at 5 months of age than infants born vaginally (Bartlett et al., 1997). With regard to GA, full-term infants have a full MR, with two phases of shoulder abduction and adduction. In contrast, premature babies often display only the abduction phase; however, prematurity is not always associated with an abnormal MR after birth (Romeo et al., 2011). Babies born before 30 weeks of gestation show an exaggerated MR, which is activated by weak stimuli (Johnson & Grubbs, 1975). Mothers of such children fear that they are startling their babies and causing them to cry, which can lead to reduced touching, lifting, and hugging of the baby by the mother. This can negatively affect the mother-baby relationship and the baby's emotional regulation.

Some of the most common uninhibited reflexes in children with suspected developmental disorders at 1–5 years of age are the PRs, including the MR (Calvin & Ramli, 2020). The persistence of a full MR beyond 6 months of life seldomly occurs, with the exception of some children with CP with spastic tetraparesis, athetosis (Paine, 1964), or intellectual disability (Futagi et al., 2012). The MR does not disappear completely (Rousseau et al., 2017); therefore, it is deemed to be uninhibited if it remains active, even if it is residual activity. An increase or decrease in intensity and other features may indicate maturation (Goldstein et al., 1938; Hunt & Landis, 1938).

The MR is a phylogenetically old behavior pattern present in all primates (Prechtl, 1965). This has been confirmed by several authors who observed that the palmar grasp reflex inhibits the MR (Brown & Fredrickson, 1977; Fredrickson & Brown, 1980; Weggemann et al., 1987), and instead of the expected arm extension, it increases the flexion (Prechtl, 1965). An infant that is already holding onto its parent cannot trigger an MR response. Increasing the flexion instead of the appearance of extension indicates a defensive function of the MR which occurs in response to a sudden (potentially threatening) stimulus and leads to the newborn embracing the mother. A similar reaction occurs in newborn orangutans,

macaques, and baboons (Katona, 1998). Since humans no longer live in trees and their infants no longer need to constantly cling to their mothers, this behavior is biologically unnecessary (Prechtl, 1965); nevertheless, it still occurs in infants and is associated with increases in stress hormones (Akbuğa&Eliöz, 2021).

Although the MR was discovered more than a century ago, many inaccuracies exist regarding the stimuli that trigger the MR. A sudden blow on the bed or table on which the infant is supported, tapping the abdomen, the extension of the infant's arms followed by a sudden release, blowing on the face, cold or warm applications to the trunk, and a sudden loss of support of the infant's head and torso (Goldstein et al., 1938; Salandy et al., 2019) can all act as the triggers. Parmelee (1964) found that the following stimuli effectively triggered the MR in children from birth to 12 weeks of age: a sudden backwards drop of the baby's head, a slap on the examination table near the baby's head, and a sudden jarring of a surface that is supporting the baby. In contrast, he found that the following stimuli were ineffective: a sudden tilting of a surface supporting the baby, a pin prick to the baby's foot, and a loud noise. Accordingly, he concluded that stimulating the infant's semicircular canals alone is insufficient for a complete MR reaction, and that the movement of the neck seems to be of key importance. Currently, the most common method to elicit the MR in an infant is the head drop method (Futagi et al., 2012). Still, many authors believe that the MR can be triggered by a loud noise (Blythe & Goddard Blythe, 2012; Desorbay, 2013; Goldstein, 1938; Weggemann et al., 1987). Moreover, Goddard Blythe (2017) suggests that the MR can be elicited by many stimuli: a sudden loud noise (auditory stimulus), pain or a change of temperature or rough touch (tactile stimulus), movement in the field of view or a change of light (visual stimulus), passive vestibular stimulation, or active movements of the child such as shaking of the head, kicking, coughing, and sneezing.

Some authors argue that an uninhibited MR in older children and adults causes excessive release of adrenaline and cortisol (Volemanová, 2020), which can lead to an increased sense of stress, threat, and fear, as well as increased anxiety, mood swings, reactivity, and sensitivity (Goddard Blythe, 2018; Grzywniak, 2016), a constant state of fight-or-flight (Brandes, 2015; Goddard Blythe, 2017; Grzywniak, 2016), adrenal gland fatigue, and a decrease in immunity. However, these theories have not yet been confirmed by empirical research.

Rousseau et al. (2017) observed that the MR often occurred immediately after the startle reflex. They proposed that the startle reflex starts with a sudden noise and is characterized by fast arm extension and adduction, and approximation of both hands. This reflex is mediated by the fear system, which controls the subcortical nuclei. The arm and hand adduction suggests that the startle reflex may be an attempt to cling onto a mother as observed in apes and monkeys. The neural mechanisms of the MR are less well-established than those of the startle reflex, but are likely to be similarly mediated by the fear system. Accordingly, the MR may be understood as an active defense behavior of the fight-or-flight response of a newborn who cannot gesture to communicate with their mother. Fur-

thermore, the crying of a newborn who did not receive any response from their mothers suggests that the separation-distress or grief/panic system may also be activated. This theory is supported by the fact that the infant calms down after being picked up and hugged by the mother. Moreover, the MR pattern immediately after birth differs from that 15 minutes later; hence there is a change from pure PRs to more infantile behaviors. Babies display gestures that indicate an intention to communicate such as eye opening, vocalization, and turning the body, head, and eyes towards a parent to seek protection. As the MR is a ritualized non-verbal form of communication that can be triggered by both the fear and grief/panic systems, the method of caring for an infant is critical. In this regard, the baby should be protected from intense sensory stimuli in the first few weeks of life. Brandes (2015) proposed that PRs are integrated during their regular use in daily routines. Movement causes babies to use reflex patterns to support nervous system maturation; thus, it is necessary to repeatedly enact PRs for the nervous system to integrate these movements. However, this does not apply to the MR, and an infant should be protected against these.

Communication from a child to the parent via the MR and the adult's proper response are the first steps to establishing affective ties and attachment in the child and bonding in the parent (Rousseau et al., 2017). Porges (2005), the author of the polyvagal theory, proposed that an integrated social engagement system in infants is built on the basis of interactions with the parent. Although babies have a limited ability to verbally communicate, they can use vocalizations, grimaces, gazes, smiles, or sucking noises. Fight-or-flight behaviors interfere with the ability to perform social engagement behaviors. Conversely, an activated social involvement system suppresses the neural circuits that support fight-or-flight or freeze responses. Similar to other mammals, humans must quickly distinguish friends from foes, assess the safety of the environment, and communicate to survive. According to the polyvagal theory, the evolution of the autonomic nervous system provides a neurophysiological basis for the emotional experiences and affective processes that are the main components of social behavior. This theory has linked the evolution of the autonomic nervous system with affective experience, emotional expression, facial expressions, oral communication, as well as random social behavior.

According to the polyvagal theory, difficulties in spontaneous social behavior are related to both visceral regulation and facial expression. Furthermore, social behavior can regulate physiological activity. In order to engage socially, it is vital for a person to feel safe. If the environment is perceived as safe, the infant can inhibit adaptive primitive neurobiological defense responses to enable social involvement. Despite its metabolic cost, the physiological fight-and-flight response to significant risks is beneficial, but can become maladaptive if it persists. Appropriate social engagement strategies are crucial to attachment formation and building social ties. Individuals diagnosed with anxiety disorders and depression have difficulties in performing social engagement behaviors such as facial expressions and motor control of the head and facial muscles.

An uninhibited MR may also influence emotional functioning (Goddard Blythe, 2017). In addition to the unpleasantness of the reflex reaction itself, the anticipation of a possible unpleasant reaction can also induce hypervigilance, and the reaction threshold is lowered. Older children with an uninhibited MR are overly reactive and hypersensitive to certain stimuli and situations in which these stimuli occur. They often present with subconscious anticipatory anxiety associated with situations in which the child has previously experienced discomfort related to the MR reaction. This could negatively impact the child's daily behavior and emotional functioning resulting in insecurity, anxiety, poor adaptability, poor attention, physical timidity, poor regulation of energy levels, labile emotions, mood swings, sensory overload in busy and noisy environments, and low tolerance thresholds for stress. Therapy aimed at lowering the level of PRs can concomitantly lower anxiety levels and mental discomfort (Goddard Blythe, 2017; Scaramella Nowinski, 2017).

Short MR latency intervals in infants are linked with subsequent long-term behavior problems such as learning difficulties, short concentration spans, and mood instabilities (Bijesh et al., 2013; Ince et al., 2019). Despite suggestions that the MR is active only in very young infants and disappears by the end of the 4th month (Goldstein et al., 1938), uninhibited MRs in older children have been reported and are often associated with an exaggerated startle reaction, which can result in hypersensitivity (Blythe & Goddard Blythe, 2012). Such hypersensitivity can overstimulate children, increase activity in the sympathetic nervous system, and thus increase the need for adrenaline and cortisol production. This can weaken stress hormone regulation. An excessive MR in infants makes them more sensitive to stimuli, and therefore they sleep worse and are less calm, more irritable, and feel more discomfort (Brandes, 2015).

The MR develops in infants before head-righting reflexes and muscle tone that supports posture (Blythe & Goddard Blythe, 2012). Thus, the uninhibited MR is related to poor balance and coordination (Berne, 2006). Goddard Blythe (2017) suggested that MR inhibition is associated with the maturation of the acoustic stapes reflex, which protects the ears from loud noises. Poor development of this reflex causes acoustic hypersensitivity and increases the activation of the MR to acoustic stimuli.

Matuszkiewicz & Gałkowski (2021) found that preschool and school-age children with DLD have a higher level of uninhibition of the MR than typically developing children. Children with an uninhibited MR have problems with linguistic development because they are unable to concentrate on understand other speech due to constantly distracting auditory stimuli from the environment (Volemanová, 2020). This is especially true of a noisy and busy environment such as school or a room where the TV is often turned on.

An uninhibited MR was observed in 81% of children with developmental dyslexia (Goddard Blythe, 2018) and in 92.8% of children with learning disabilities (Bilbilaj et al., 2017). Similarly, an uninhibited MR has been observed in children with poor control of eye movements which cause information processing

problems (Berne, 2006), those with VPD (Hinkley & Smith, 2011), with the inability to ignore irrelevant visual information (Goddard Blythe, 2017; Grzywniak, 2016), and with reduced saccadic accuracy (González et al., 2008).

According to Calvin and Ramli (2020), the lack of MR inhibition negatively impacts concentration and focus in children, which can cause hyperactivity and hypersensitivity, and may be an early sign of future anxiety. Children with ADHD exhibit a higher level of an uninhibited MR than typically developing children (Konicarova& Bob, 2012). Although the MR does not directly affect any ADHD symptoms, it has indirect effects that are mediated by its relationship with other PRs such as the asymmetrical tonic neck reflex, symmetrical tonic neck reflex, and tonic labyrinthine reflex (Taylor et al., 2004). These results support the theory that the MR acts as a gateway for the inhibition of other reflexes.

An uninhibited MR in children can be linked to overweight, confusion, rapid fatigue (especially in noisy environments), hyperactivity, destructive behavior, or a tendency to withdraw to avoid excessive stimuli (Bilbilaj et al., 2017). A lack of MR inhibition also contributes to hypersensitivity to noise and light, poor concentration, mood swings, anxiety, hyperactivity, poor physical endurance, reduced motor skills, decreased immunity, shyness, and low self-esteem (Desorbay, 2013). Jeżewska-Krasnodębska and Krasnodębski (2018) reported that the MR is often uninhibited at high levels (75–100%) in children with ASD. Additionally, these children are hypersensitive and anxious, withdraw from difficult situations, have difficulties establishing interpersonal contacts, have problems with naming emotions and showing feelings, and are overexcited and aggressive.

Despite clinical observations that link the MR with emotional difficulties such as anxiety, no study has established definitive correlations. Thus, this study aimed to address the following four questions: (1) Do children with anxiety have a higher uninhibited MR level than children without anxiety? (2) Are there sex differences in MR levels? (3) Does the relationship between the MR level and anxiety change with age? (4) Do children with higher MR levels experience anxiety more frequently? This study is the first to report comprehensively collected data on the MR and anxiety in preschool and school-age children.

MATERIAL AND METHODS

Participants

An a priori power analysis was conducted using G*Power 3 (Faul et al., 2007) to test the difference by means of an F test using a medium effect size (.25) and an alpha of .05. Results showed that a total sample size of 279 participants was required to achieve a power of .95.

A total of 374 children (225 boys and 149 girls, M_{age} = 9.6 years, range: 4.0–17.9) participated in this study. The study is part of a larger study on uninhibited PRs and developmental, emotional, and educational disorders in children. The children were recruited via Facebook posts by therapists studying the Institute

for Neuro-Physiological Psychology (INPP) method of stimulation and inhibition of PRs. The participants' parents completed a screening questionnaire in which one of the questions asked whether the child presented with any symptoms of anxiety. Based on the answer, children were divided into groups with or without anxiety. The anxiety and non-anxiety groups included 182 (60% boys, 40% girls) and 192 (60% boys, 40% girls) children, respectively. The participants were divided into four equal age groups: youngest children (age ≤ 7.6 years), younger middle children (age 7.7–9.1 years), older middle children (age 9.2–10.8), and oldest children (age ≥ 10.9). According to the information provided by the parents, all children had an intellect in the normal range, did not have a diagnosis of ASD, and did not have acquired brain injuries. All participants were of Polish origin (Caucasian race). Demographic characteristics such as socio-economic status and sexual orientation were not controlled.

Children were examined in the presence of their parents at their homes or in other environments (i.e., offices, rooms at nursery schools or schools), while ensuring protection of the child's privacy. Parental and children's consent was obtained prior to participation. This study was approved by the appropriate ethics committee. All research procedures were conducted by trained examiners. No work was preregistered.

Procedures and Stimuli

Measuring the Moro Reflex

The MR was assessed using two tasks:

1. *The MR falling task.* Participants were required to stand upright with their head tilted slightly back, arms raised and abducted, hands relaxed and directed towards the body, and eyes closed.The examiner clapped, and participants fell backward from 10° to a maximum of 30° and were firmly caught by the examiner.
2. *The MR tilting task.* Participants were required to stand in an upright position with their head tilted slightly back, arms raised and abducted, hands relaxed and directed towards the body, and eyes closed. The examiner tilted the participant's body backward to put them on their heels. When participants were standing on their heels and had shifted their weight into the examiner's hands, the examiner moved their hands away to allow the participants to fall backward from 10° to a maximum of 30° and then firmly caught the participants.

The examiners were taught by the author to correctly score the tasks during a 2-day training course: they tested the adults and children, assessed the results together, watched the recordings of the examined children and, accordingly, learned how to score the tasks.

Each task was scored from 0 to 4, where 0 indicated no signs of the MR and 4 indicated 100% of the residual uninhibited MR. In both the tasks, the participants were assured that they would be held by the examiner, were informed of what was going to happen next, and were instructed not to change their hand

and head position during the task. The examiner observed the stability of the arm positions, the participants' emotional state and whether their face color changed (i.e., flushed or pale), an unwillingness to lean backward or the presence of blocking behavior (e.g., compensatory head movements, withdrawal of feet, opening of eyes), and any behavioral changes that occurred due to the task (i.e., becoming calmer, withdrawing, or becoming more agitated). MR task scoring was as follows:

- 0 = no reaction in the arms and hands, the arms remained in the starting position;
- 1 = slight outward movement of the arms (abduction);
- 2 = visible partial abduction of the arms, an intake of breath;
- 3 = 75% abduction of the arms and/or signs that the participant is shaken by the task procedure;
- 4 = full abduction of the arms and/or significant irritation during the task procedure—possible screaming or significant resistance to the task (e.g., complete blocking by withdrawing the legs), or obvious signs of anxiety.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Version 27.0 (Armonk, NY, USA). Descriptive statistics were computed for the MR. The analyses were conducted across two test groups: participants with anxiety (anxiety group) and those without anxiety (non-anxiety group). Kolmogorov–Smirnov tests were conducted to determine normal distribution of the data. Two-way analysis of variance (ANOVA) tests were performed to compare the anxiety and non-anxiety groups according to sex and age. The main effects and interactions were assessed. One-way ANOVA tests were performed to compare groups classified according to the level of MR uninhibition (0% vs. 25% vs. 50% vs. 75% vs. 100%). The significance level for all analyses was set at $p < .05$. Bonferroni corrections were used in all the analyses and for main and interaction effects. Additionally, a cluster analysis was performed using the k-means cluster method. An outlier test was performed and no anomalies were found.

RESULTS

Descriptive Statistics

The descriptive statistics of the MR score for all participants (see Table 1) and performed Kolmogorov–Smirnov tests to determine if the data differed from theoretical normal distributions were calculated. This showed that the obtained data

Table 1. Descriptive statistics for the Moro reflex score (N = 374)

Assessment	R	*M*	*SD*	Sk	Kurt	*MAD*
MR score	0–8	4.34	2.99	−.07	−1.49	2.99

Note. R = range; *M* = mean; *SD* = standard deviation; Sk = skewness; Kurt = kurtosis; *MAD* = mean absolute deviation; MR = Moro reflex

significantly deviated from a normal distribution. Kurtosis statistics calculated for the MR index showed a marked platykurtosis, indicating a large dispersion of results in relation to the mean. However, no marked skewness was observed.

The Association Between Anxiety and the MR Score

To assess differences in the MR score between participants in the anxiety and non-anxiety groups, a two-way ANOVA with a 2 × 2 scheme was performed (Table 2). This revealed a significant main effect of sex (p = .043) and group (p = .002). The MR score was higher in girls than in boys, and was also higher in children with anxiety than in children without anxiety. No significant interaction effect was observed.

Analysis of pairwise comparisons revealed statistically higher MR scores in boys than those in girls (Figure 1). The MR score was lower in the non-anxiety

Table 2. Anxiety and sex vs the Moro reflex score (N=374)

Group		*M*	*SD*	*F*	*p*	η^2	Post-hoc
A	Boys	4.09	3.008	4.127	.043	.011	A < B*
B	Girls	4.73	2.949				
I	Non-anxiety	3.85	3.053	9.875	.002	.026	I < II**
II	Anxiety	4.87	2.853				
IA	Non-anxiety boys	3.53	3.009	.348	.556	.001	IA < IB***
IB	Non-anxiety girls	4.34	3.075				IA < IIA**
IIA	Anxiety boys	4.69	2.902				
IIB	Anxiety girls	5.14	2.775				

Note. *M* = average; *SD* = standard deviation; *F* = distribution; *p* = significance level; η^2 = effect size. Post-hoc comparisons were performed using the Bonferroni test.
*p< .05; **p< .01; ***p< .099

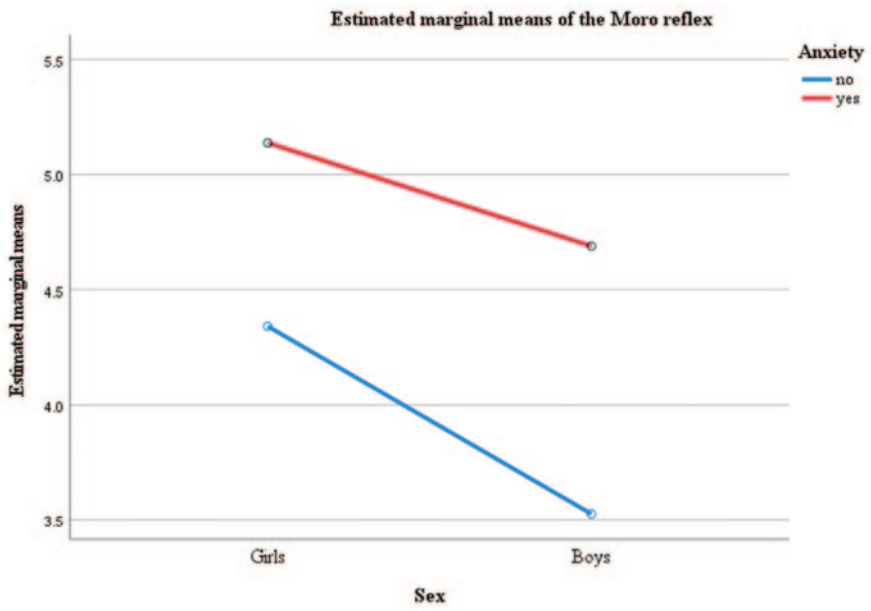


Figure 1. Anxiety and sex vs the Moro reflex score (N=374)

boys group than that in the anxiety boys group (p = .003) and in the non-anxiety girls group (p = .061).

To assess differences in the MR score between participants in the anxiety and non-anxiety groups, a two-way ANOVA with a 2 × 4 scheme was performed (Table 3). The results revealed significant main effects of age (p < .001) and group (p = .007). The MR score was higher in the youngest children compared to that in the oldest children (p = .017), and higher in younger middle children compared to that in older middle (p = .022) and oldest children (p < .001). The MR score in children with anxiety was higher than that in the children without anxiety (p = .007). A trend for a significant interaction (Figure 2) was observed (trending at p = .067), wherein scores were significantly higher for the youngest children in the anxiety group than those for the youngest children in the non-anxiety group (p < .001), older middle children in the anxiety group (p = .025), and oldest children in the anxiety group (trending at p = .070). Moreover, the MR score was significantly lower in the oldest children in the non-anxiety group than that in the oldest children in the anxiety group (p = .027) and younger middle children in the non-anxiety group (p < .001).

Children were categorized based on MR scores, and the frequency of anxiety in children within each category was assessed. As predicted, children with the lowest MR scores of the residual had anxiety with the least frequency. Among children with a 0%, 25%, 50–75%, and 100% uninhibited MR, 25.4%, 48.7%, 50.0%, and 58.7% children experienced anxiety, respectively. Bonferroni's post-hoc tests showed that frequency in anxiety significantly differed between children with 0% uninhibited MR and children with 100% MR (p< .001). A trend was observed between the frequency of anxiety in children without an MR and that in

Table 3. Anxiety and age vs the Moro reflex score (N=374)

Group		*M*	*SD*	*F*	*p*	η^2	Post-hoc
A	Youngest	4.88	2.993	6.585	.000	.051	A > D**
B	Younger middle	5.23	2.725				B > C**
C	Older middle	3.97	2.922				B > D**
D	Oldest	3.35	2.995				
I	Non-anxiety	3.85	3.053	7.484	.007	.020	I < II**
II	Anxiety	4.87	2.853				
IA	Non-anxiety youngest	3.81	3.010	2.410	.067	.019	IA < IIA**
IB	Non-anxiety younger middle	5.22	2.725				ID < IID**
IC	Non-anxiety older middle	3.94	2.972				IB > ID**
ID	Non-anxiety oldest	2.83	3.056				IIA > IIC**
IIA	Anxiety youngest	5.68	2.740				IIA > IID***
IIB	Anxiety younger middle	5.24	2.756				
IIC	Anxiety older middle	4.00	2.897				
IID	Anxiety oldest	4.16	2.746				

Note. *M* = average; *SD* = standard deviation; *F* = distribution; *p* = significance level; η^2 = effect size; youngest = children aged ≤ 7.6 years; younger middle = children aged 7.7–9.1 years; older middle = children aged 9.2–10.8 years; oldest = children aged ≥ 10.9 years. Post-hoc comparisons were performed using the Bonferroni test.
*p< .05; **p< .01; ***p< .099

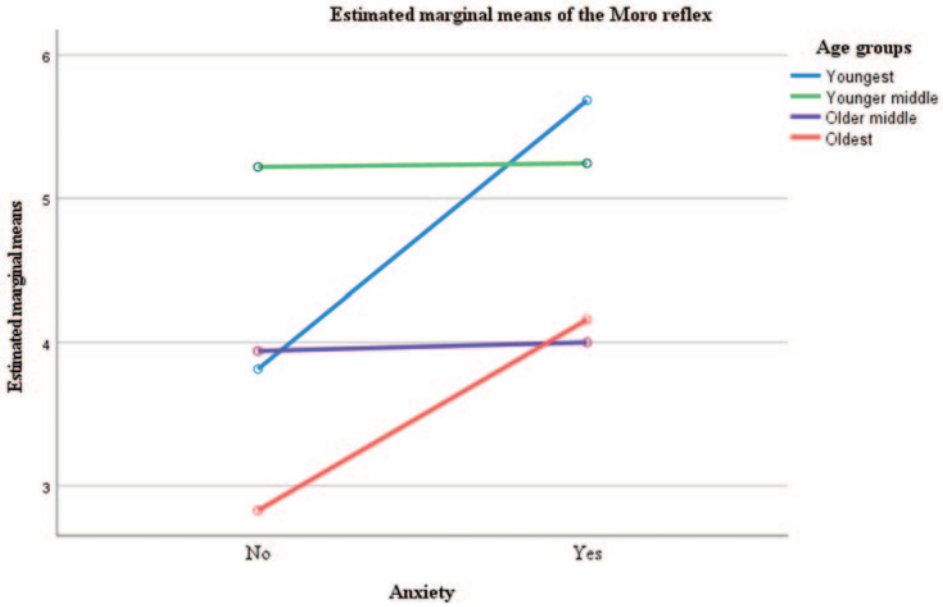


Figure 2. Anxiety and age vs the Moro reflex score (N=374)

children with a 75% uninhibited MR (p = .067), in children with a 50% uninhibited MR (p = .076), and in children with a 25% uninhibited MR (p = .063).

Further analyses were conducted using the k-means clustering method. The probability of being anxious increased with increasing levels of an uninhibited MR in boys. In boys with a completely (100%) uninhibited MR, the probability of being classified in the cluster of children with anxiety increased almost three-fold. In contrast, in boys with a completely (0%) inhibited MR, the probability of being classified to the group without anxiety decreased almost three-fold.

DISCUSSION

Anxiety disorders are prevalent in children and adolescents, increase the risk of other mental disorders, and impair social and academic life (Freidl et al., 2017). Therefore, it is critical to identify causal factors associated with anxiety, especially in the context of the COVID-19 pandemic, which has significantly intensified anxiety symptoms in children and adolescents. Recent studies have shown that pandemic-related stressors – such as social isolation, school closures, and uncertainty – have led to a measurable increase in general anxiety symptoms, particularly among youth aged 11–15 years (Ludwig-Walz et al., 2023; Panchal et al., 2023; Grzywniak i Krupa 2025, Pąchalska 2025). In Poland, additional stressors such as the war in Ukraine have further exacerbated mental health challenges in this age group (Grzankowska et al., 2025). These findings underscore the growing importance of early identification of neurodevelopmental

markers associated with anxiety, such as the uninhibited Moro reflex (Grzywniak & Krupa, 2025; Pąchalska, 2025).

This study confirmed previous suggestions that an uninhibited MR is associated with anxiety (Brandes, 2015; Goddard Blythe, 2017; Grzywniak, 2016) and established that the association depends on the age and sex of the children. It was found that children with anxiety had higher MR scores than children without anxiety. Furthermore, boys with anxiety had a higher MR score than boys without anxiety; however, this trend was not significant in girls. Importantly, in the group of boys with a completely (100%) uninhibited MR, the probability of anxiety increased almost three-fold. Moreover, based on our clinical experience, the number of children with anxiety decreased during an INPP motor program aimed at lowering the MR. Altogether, these findings suggest that lowering the MR could also reduce anxiety. On the other hand, girls had a higher MR score than boys, and the MR scores in girls without anxiety did not significantly differ from those in girls with anxiety. Additionally, girls without anxiety had a higher MR score than boys without anxiety. Together, this could indicate that the threshold at which the MR contributes to anxiety in girls may be higher.

Future studies should employ a standardized tool such as the State-Trait Anxiety Inventory by Spielberger et al. (2011) to measure anxiety levels. This would limit the study group to children ≥ 10 years of age; however, given the results obtained in this study, it is possible that an older sample could provide the optimal solution. In this study there was observed that only the youngest and the oldest children with anxiety had a higher level of an uninhibited MR compared to children without anxiety in the same age groups. In the groups of middle younger and middle older children, no differences were observed between the anxiety and non-anxiety groups. The differences in the youngest children may be partly due to the developmental severity of anxiety at this age, and incomplete neuromotor maturation.

A comparison of the prevalence of anxiety among children with different levels of uninhibited MR revealed notable findings. Children with the maximum level of the MR (100%) experienced anxiety significantly more frequently compared to children in whom no symptoms of the MR were observed (0%). A trend in the prevalence of anxiety was also found when children with the maximum MR (100%) were compared to children with a lower MR (25%, 50%, and 75%). This suggests that an uninhibited MR may indeed be relevant to the occurrence of anxiety disorders, but only at the maximal level.

It is worth noting that the incomplete inhibition of the MR was observed in the majority of children, regardless of the group. Although children with anxiety had a higher MR score than children without anxiety, the average uninhibition of the reflex in children without anxiety was not very low (almost 50% persistence).

Pecuch et al. (2020) reported that the MR is the least inhibited PR in preschool and early school age children, and assessment of the MR is often accompanied by a strong emotional reaction in these young children. This suggests that children with developmental disabilities (Akbuğa&Eliöz, 2021; Brandes, 2015;

Chinello et al., 2018; González et al., 2008; Jeżewska-Krasnodębska&Krasnodębski, 2018; Konicarova& Bob, 2012; McPhillips & Jordan-Black, 2007; Taylor et al., 2004) as well as typically developing children have a slower maturation of the PR system than previously assumed (Capute et al., 1982). Accordingly, the relationship between this reflex and anxiety should be investigated in an older population, especially given that preschool children in the general population have a lower PR than school-age children (Gieysztor et al., 2017).Furthermore, studies indicate that adolescent girls (Bitsko et al., 2018) and adult women, but not preschool-aged girls and younger women (McLean et al., 2011), have higher levels of anxiety than adolescent boys and adult men. This provides another reason to perform research in older populations.

This study confirmed that higher levels of an uninhibited MR in children are associated with anxiety, and that anxiety was more frequent in children with the highest levels of uninhibition. These findings support theories that associate the MR with the fight-or-flight response (Brandes, 2015; Goddard Blythe, 2017; Grzywniak, 2016). Rousseau et al. (2017) proposed that the MR can be controlled by both fear and grief/panic systems, which provoke increased parental care for an infant through ritualized behaviors and non-verbal communication. The proper response of an adult to the MR in an infant establishes affective ties and attachment in children and promotes bonding with the parent. In turn, these are the basis for shaping a child's social engagement skills, which cannot develop properly when the fight-or-flight reaction is activated. A person who feels safe readily engages socially. Research has shown that people with anxiety have difficulty performing socially engaging behaviors (Porges, 2005). Therefore, an uninhibited MR that activates the fight-or-flight response in post-infancy children will have a negative impact on establishing attachment and social engagement skills.

Limitations

One limitation of this study is that there were unable to reveal a causal relationship between anxiety and the level of an uninhibited MR with the available data. Although it was assumed that uninhibited MR increases anxiety in children, it cannot be ruled out that the opposite is true. Another limitation is the absence of standardized test batteries to measure MR, which may make it difficult to compare the results of this study with those of studies conducted by other researchers. Furthermore, the group with anxiety may have been heterogeneous in terms of the type and severity of anxiety. Additionally, this study lacked clear diagnostic criteria for anxiety in the participants. Failure to ensure the homogeneity of the group of children with anxiety may have affected the credibility of the results obtained. Thus, it is necessary to conduct further research on the association between the MR and anxiety, with particular attention to the use of standardized anxiety testing tools and clear diagnostic criteria.

Despite these limitations, our findings provide novel insights into our understanding of anxiety development in children. The study yielded valuable results regarding the relationship between anxiety and motor development at a funda-

mental level. Confirmation of these findings in a future study that analyzes the severity of anxiety will further our understanding of anxiety and its relationship with an uninhibited MR. This could ultimately lead to improved diagnoses and treatments of children with anxiety.

CONCLUSIONS

This study provides the first empirical evidence of a positive association between MR and anxiety in children. The relationship was particularly pronounced in cases of completely uninhibited MR, suggesting a potential neurodevelopmental marker for anxiety risk

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