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ORIGINAL CONTRIBUTION

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Evaluation of neuromotor deficits in children with autism and children with a specific speech and language disorder

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Abstract Several studies have described problems in motor functions in children with autism and children with a specific speech and language disorder. The purpose of this study was to identify neuromotor deficits in these neurodevelopmentally impaired children. A standardised neurological examination was performed in 11 children with childhood autism, 11 children with an expressive language disorder, 11 children with a receptive language disorder and 11 control children. The children were matched for age and non-verbal IQ, not for gender. All children had a non-verbal IQ above 85. The neurological examination procedure allowed for a qualitative and quantitative assessment of five specific neurological subsystems: fine and gross motor functions, balance, coordination and oral motor functions. The high-functioning children with autism and the children with a specific language disorder (expressive or receptive) had more motor problems than the control children on most neurological subsystems. There were few statistically significant differences between the three groups of developmentally impaired children. The frequent co-occurrence of verbal and non-verbal, in particular neuromotor, deficits in developmentally impaired children put an additional burden on the development of these children and should be diagnosed as early as possible.

Key words specific language disorder – autism – neuromotor problems – neurological evaluation

Introduction

Childhood autism is characterised by the occurrence of qualitative impairments of language and communication, qualitative impairments in social interaction as well as the occurrence of stereotyped behaviours. Specific developmental language disorders are characterised by an isolated deficit in language acquisition in the early stages of development [27]. Both types of developmental disorders thus share deficits in language and/or communication problems as part of their core symptoms.

In addition to the core symptoms of these developmental disorders, numerous studies have demonstrated that children with autism and children with language impairment show a wide range of other problems which put a further burden on their development. Motor problems have been one of the most frequently reported nonverbal deficits in these children [1, 5, 8, 12, 16, 17, 21–23, 26]. In the literature, these types of motor deficits were often categorised under the heading "soft neurological signs" and the children were given the diagnosis "motor coordination disorder" [10, 21, 25].

In childhood autism, relatively little attention has been paid to the motor deficits which have been regarded as of less importance or belonging to a co-occurring syndrome [12, 14]. Although it is not a diagnos-

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tic criterion, clumsiness has been proposed as an essential feature of Asperger's syndrome [4, 16]. However, the extent to which this symptom is specific to this subtype of pervasive developmental disorders is not clear. Ghaziuddin and Butler (1998) compared a group of children with Asperger's syndrome with children with childhood autism and children with pervasive developmental disorders not otherwise specified. Coordination disorders were found in all three groups and children with Asperger's syndrome were found to be less impaired than the two other groups [5]. Leary and Hill (1996) reviewed different types of motor disturbances associated with autistic disorder and discussed motor deficits as a probably impairing feature for the development of adequate communicative and interactive skills in these children [12].

Fine motor problems, coordination difficulties as well as gross motor deficits and balance problems have been found in language impaired school children [18, 24]. A wide variety of tasks have been used to evaluate the motor skills of these children. A number of studies focused on one type of task (1, 2, 8), whereas other studies used a broader range of motor tasks [18, 19, 21, 24]. Several studies stressed the relevance of fine motor deficits in the finger and hand functions as well as in the oral and speech motor functions [1, 2, 24]. Fine motor problems of the fingers and hand seem to be most pronounced on the tasks requiring fast tapping skills [18, 22]. Studies using a broader range of motor tasks showed, however, that motor deficits were not restricted to tasks involving the rapid programming of sequential movements (as in speech motor movements or tapping tasks) and that balance tasks proved to be one of the most discriminating measures [21, 19].

Several studies showed that the detection of motor problems in developmentally impaired children was particularly relevant for two reasons: Firstly, motor problems put an additional burden on the development of children. These deficits had a considerable impact on daily activities (playing, eating, writing and drawing, sport games, etc.) and impaired the social integration of the child in his peer group [10, 12]. Secondly, longitudinal studies showed that children with problems in fine motor functions and coordination had a higher risk of developing learning and behavioural problems when they reached school age [7, 13].

The type of motor deficit associated with autism or specific language disorder is not clear. The purpose of the present study was to compare the motor performance of high-functioning children with childhood autism (F84.0) with the motor performance of children with a specific speech and language disorder (expressive or receptive) and of control children. We used a standardised neurological examination to evaluate qualitatively and quantitatively different motor domains in these four groups of children.

Method

Subjects

The normal children participating in this study were recruited from regular primary schools. The children with childhood autism and the children with a language disorder were recruited from the department for developmental disorders of the Heckscher Klinik in Munich and special schools for children with language problems.

All children were examined individually and extensively by a multiprofessional team and diagnoses were established according to ICD-10 research criteria. On the basis of these criteria, 11 children were assigned to the group "childhood autism", 11 children to the group "expressive language disorder", 11 children to the group "receptive language disorder" and 11 children were selected as control children. Two child psychiatrists with longstanding experience in the field of autism and pervasive developmental disorders as well as in the field of specific language disorders made the assignment to the diagnostic groups.

Children born before 38 weeks of gestation were excluded from the study, as well as children with a history of cerebral palsy, epilepsy or any other kind of diagnosed major neurological condition. Bilingually raised children, children with a history of hearing problems, as well as children with current hearing or sight problems were also excluded from the study. Non-verbal intelligence was measured with the non-verbal scale of the Kaufman Assessment Battery for Children [11]. All children had to have a non-verbal IQ of at least 85 to be included in the study.

Language skills were assessed with the Heidelberger Sprachentwicklungstest (Heidelberg Test of Language Development) [6]. The subtest "IS: Imitation grammatischer Strukturen (imitation of grammatical structures)" was used to evaluate expressive language skills, the subtest "VS: Verstehen grammatischer Strukturen (comprehension of grammatical structures)" for the receptive language skills. For the Heidelberger Sprachentwicklungstest T-values between 40 and 60 are considered to be normal (mean T-value 50, 1 SD = 10).

To be included in the group "specific expressive language disorder", there had to be a two standard deviations discrepancy between the measure of expressive language and chronological age as well as a one standard deviation discrepancy between the language measure and the measure of non-verbal intelligence. The receptive language skills measured by the subtest VS had to be normal (T-value above 40).

To be included in the group "specific receptive language disorder", there had to be a two standard deviations discrepancy between the measure of receptive language and chronological as well as a one standard deviation discrepancy between the receptive language measure and the measure of non-verbal intelligence. Most children with the diagnosis "receptive language disorder" also had an expressive language disorder. This is in accordance with the ICD-10 definition of a receptive language disorder.

To be included in the group of children with autism, the children had to fulfil the research criteria of the ICD-10 for childhood autism and have a normal non-verbal IQ. Only 11 children meeting both inclusion criteria could be recruited during the period of the study.

To be included in the control group, children had to reach normal values on all language and intelligence measures. The control children were matched as closely as possible to the clinical groups with respect to age and non-verbal IQ.

Statistical analysis (one-way analysis of variance) showed that the four groups did not differ significantly from each other with respect to non-verbal intelligence ($F = 1.2$, $p < 0.3$). The children with autism were significantly older than the children of the three other groups ($F = 4.5$, $p < 0.008$). The children with a receptive language disorder had significantly lower scores on the subtest VS than the three other groups ($F = 9$, $p < 0.000$). These children also differed significantly from the control group on the subtest IS ($F = 30$, $p < 0.000$). The children with an expressive language disorder differed significantly from the control group on the subtest IS only ($F = 30$, $p < 0.000$). The group of children with the ICD-10 diagnosis "receptive language disorder" was thus a mixed group with respect to the language skills affected. None of the children in this group had a purely receptive language disorder. There was a clear preponderance of boys in the group of children with an expressive language disorder. The characteristics of the sample are summarised in Table 1.

Table 1 Mean (SD) for age, non-verbal intelligence, receptive and expressive language skills as well as sex ratio for each group

	Autism N = 11	Expressive language disorder N = 11	Receptive language disorder N = 11	Control group N = 11
Mean age (in months)	118	97	100	97
(SD)	(28)	(12)	(15)	(7)
Mean non-verbal intelligence	103	106	98	105
(SD)	(14)	(10)	(9)	(13)
Mean score VS (T-value)	39	43	27	50
(SD)	(18)	(8)	(4)	(7)
Mean score IS (T-value)	38	21	18	51
(SD)	(15)	(7)	(4)	(8)
Boys : girls	8 : 3	10 : 1	6 : 5	10 : 1

VS comprehension of grammatical structures
IS imitation of grammatical structures
SD Standard deviation

Procedure

In this study, we used a standardised neurological examination procedure [20]. All children were assessed individually by the same person (K. M., medical doctor with training in developmental neurology) who had been highly trained in the administration and the scoring procedure of the examination. This person was blind to the group the subjects had been assigned to. All sessions took place in a quiet room of our research building and were videotaped.

The neurological examination grouped the different items in five different domains: fine motor skills (five items: drawing, cutting, nut and bolt screwing, sequential finger opposition, and a pegboard task), gross motor skills (four items: stepping, running, stair climbing and muscle tone), coordination (four items: hand pro-supination, toe-heel alternation *(alternate quick toe/heel-tapping on the floor)*, hand closing simultaneously right and left *(holding hands up and open, quick closing and opening of the hands)*, hand closing alternately right and left), balance (four items: standing quietly on one leg, hopping on one leg, toe gait, heel gait), oral motor skills (four items: lip movements, two types of tongue movements, quality of oral movements during speech). For each item, the optimal achievement was explicitly described, as well as two different degrees of suboptimal achievement. Optimal achievement in relation to the age of each child was rated as 0, the suboptimal levels as 1 or 2, depending on the degree of the impairment. The scores of all items in one domain were added up. This summed score gave information on the degree of optimality/impairment in each of the five domains. To obtain an overall measure of the neuromotor impairment, the summed scores of the five motor domains were also totaled. This summed score is called the "global neuromotor impairment score" (GNS).

In addition to these qualitative ratings, quantitative ratings in the form of performance time for the domains of fine motor skills (sequential finger movements, time to complete five cycles), coordination (hand pro-supination, time to complete ten cycles) and balance (maximum time standing on one leg, up to a maximum of one minute) were provided. The performance time was recorded separately for the right and the left side.

For each child, handedness was assessed with a ten item inventory: writing, drawing, using scissors, using knife, using spoon, throwing a ball, tooth-brushing, opening a box, using a broom, striking a match. A child was classified as being right/left-handed when 8 out of 10 items were performed with the right/left hand [20].

The reliability of the items had been established in a pilot study. The videotapes of 10 children (6 language impaired children and 4 control children) were evaluated by eight pairs of raters. All raters were trained extensively in the administration and the scoring system of

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the neurological procedure in a training seminar. For all items used in this study, kappa was above 0.6 [15].

Statistical analysis

Multivariate analyses were conducted to detect significant left/right differences and gender differences. The dependent variables were the motor domains and the factors "side dominant/non-dominant" and "gender". Differences in handedness between the three groups were calculated with the Chi-square test. A one-way ANOVA analysis of variance was used to assess differences between the children with autism, the two groups of language impaired children and the control children in the quality of their motor performances and in performance time.

Results

Handedness in the examination groups

Hand dominance was determined for each child with a ten item inventory. In the control group, one out of 11 children was left-handed. One out of 11 children in the group of children with an expressive language disorder, two out of 11 children in the group of children with a receptive language disorder and one out of 11 children with autism were left-handed. Group differences were non-significant.

Left/right differences and effect of gender on the neuromotor scores

The qualitative and quantitative assessment of the motor domains of fine motor functions, coordination and balance was performed separately for the dominant and the non-dominant side of the body. For these three motor domains, differences between the scores of the dominant and the non-dominant side of the body were calculated. No significant differences could be detected for any of the four groups. For all further statistical analyses, we used the scores of the dominant side as reference. For the motor domains "oral motor function" and "gross motor function", there was a global assessment, with no dominant/non-dominant distinction.

There were no statistically significant differences between boys and girls on any of the five motor domains for any of the four groups. For further analysis, data of girls and boys were pooled.

Qualitative assessment of motor functions

The motor performance of the developmentally impaired children was qualitatively clearly deficient (Table 2: fine motor functions $F = 5.4$, $p < 0.003$; oral motor functions $F = 3.8$, $p < 0.03$; coordination $F = 1.3$, $p < 0.2$; balance $F = 4.9$, $p < 0.001$; gross motor functions $F = 6$, $p < 0.001$).

Post-hoc analysis (Scheffe post-hoc test for multiple comparisons) showed statistically significant differences ($p < 0.05$) between the control children and the children with an expressive language disorder/receptive language disorder on all motor domains except coordination. Differences between the control children and the children with autism were statistically significant ($p < 0.05$) for the motor domains fine motor functions, gross motor functions and balance, whereas no significant differences emerged on the oral motor functions and the coordination tasks.

Quantitative assessment of motor functions

The measurement of performance time gave a quantitative assessment of three motor domains. The performance of the developmentally impaired children was inferior to the performance of the control children except for the domain of coordination (fine motor functions $F = 3.9$, $p < 0.01$; coordination $F = 2.9$, $p < 0.5$; balance $F = 4.1$, $p < 0.003$). For the domain fine motor skills, the developmentally impaired children were slower in executing a fixed number of movement cycles. For the domain balance, they were less able to stand quietly on one leg for a determined period of time. Post-hoc analysis

Table 2 Qualitative assessment of motor functions: means (SD) on five motor domains

Motor domain	Autism N = 11	Expressive language disorder N = 11	Receptive language disorder N = 11	Control group N = 11
Fine motor functions (maximal impairment score = 16)	11.5 (3)	11.7 (1.6)	12 (2.7)	7.1 (1.8)
Oral motor functions (maximal impairment score = 10)	5.7 (1.1)	6.4 (1.3)	6.6 (1.5)	4.8 (0.7)
Coordination (maximal impairment score = 10)	5.2 (1.1)	5 (0.9)	5.2 (1.4)	4.4 (0.6)
Balance (maximal impairment score = 12)	7.2 (1.7)	7.7 (1.6)	7.5 (1.6)	5.4 (1.4)
Gross motor functions (maximal impairment score = 10)	7.1 (1.4)	6.5 (1.1)	6.4 (1.1)	5.1 (0.4)

(Scheffe post-hoc test for multiple comparisons) showed statistically significant differences ($p < 0.05$) between the control children and the children with an expressive language disorder on the fine motor tasks and the balance task. The children with a receptive language disorder and the children with autism performed significantly worse than the control children on the balance task only. The results of the analysis are summarised in Table 3.

Influence of age on motor functions

The children with autism were significantly older than the language impaired children and the control children. Therefore, the influence of age on the motor scores of each domain was controlled for with a co-variance analysis. For all motor domains, the group factor (control children versus developmentally impaired children) proved to be the main effect, whereas the age of the child did not have a statistically significant effect on the motor scores (F between 0.32 and 1.32, p between 0.2 and 0.6).

Distribution of the GNS in the four groups

To obtain an overall measure of the neuromotor impairment, the summed scores of the five motor domains were added up. This summed score is called the "global neuromotor impairment score" (GNS, maximal impairment score = 48). Fig. 1 gives an overview of the distribution of this score in the four groups. Although there was some overlap between the groups (especially for the group of children with a receptive language disorder, children with autism and the control group), there was a clear difference between the developmentally impaired children and the control children.

Table 3 Quantitative assessment of motor functions: performance time (mean in seconds and SD) on three motor domains

Motor domain	Autism N = 11	Expressive language disorder N = 11	Receptive language disorder N = 11	Control group N = 11
Fine motor functions	13.1 (3.9)	15.4 (3.1)	13.9 (3.3)	11.5 (2.5)
Coordination	9.9 (1.5)	9.6 (1.6)	9.6 (1.4)	8.7 (1.6)
Balance	20 (19)	23.8 (16)	31.6 (23.8)	50 (17)

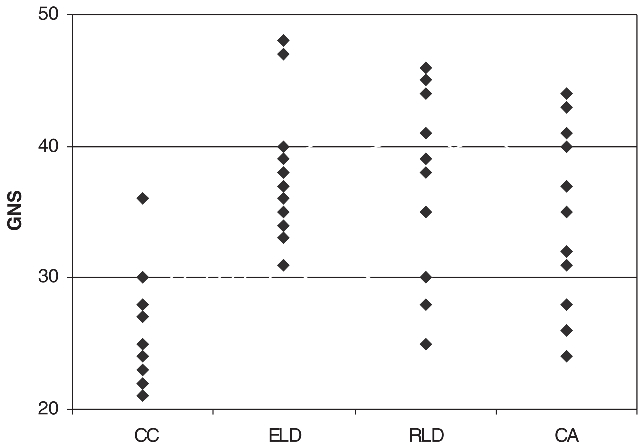

Fig. 1 Distribution of the global neuromotor impairment score in the four examination groups

Discussion

The purpose of this study was to evaluate neuromotor functions in three samples of developmentally impaired children, using a standardised neurological schedule. This allowed for both a qualitative and a quantitative assessment of different motor domains. Through this procedure it was possible to differentiate the type of neuromotor deficit in children with autism and children with a specific language disorder (expressive or receptive language disorder). The results of our study showed that the three groups of developmentally impaired children had more neuromotor problems than the control children, and that these deficits affected several motor domains. All developmentally impaired children, including those with infantile autism were of normal intelligence, so that the results cannot be explained as the consequence of a general mental retardation. There were few significant differences between the three groups of developmentally impaired children.

The overall motor performance of the children with autism was qualitatively clearly impaired in this sample. This is in accordance with several studies reporting an excess of motor problems in children with autism [5, 9, 12, 14, 26]. The occurrence of neuromotor deficiencies in these children was generally interpreted as an indication of a biological factor in the aetiology of autism [9, 14, 26].

Some of the recent literature on motor deficits in autism focused more particularly on children with Asperger's syndrome, a subtype of pervasive developmental disorders. The findings of these studies were not unitary. Some authors stressed the relevance of clumsiness in these children and even suggested the inclusion of motor clumsiness as a diagnostic criterion of Asperger's syndrome [4]. Our results, however, showed that motor problems were also quite common in high functioning children with autism so that motor problems are probably non-specific for Asperger's syndrome.

The motor performance of the language impaired children in our sample was less optimal in quality than the performance of the control children. This is in accordance with a wide body of literature reporting on the motor deficits in these children [1, 8, 19, 22, 24]. The qualitative data of the study indicated that the neuromotor impairment was not an isolated deficit in one specific domain (e. g. fine motor functions) but that most motor domains were equally involved. This is also in accordance with results of other studies [19, 21, 24]. The close association between motor and language development in language impaired children has often been interpreted in terms of delayed maturational processes of the central nervous system [3].

The qualitative data of this study demonstrated more clear-cut differences between the clinical groups and the control group than the quantitative data (except for the balance task). We hypothesised that two effects probably contributed to this result: Firstly, there might have been a trade-off between speed and accuracy of movement completion in the sample. The instruction on the timed tasks was to execute the movement cycles as fast and as correctly as possible. Though both aspects of movement completion were equally stressed, our observation was that the children tended to execute as fast as possible, which meant, at least for the language impaired children, a considerable loss of quality and accuracy (movements were inaccurate, pro-supinations were not done completely). Secondly, the number of movement cycles which were timed for the fine motor domain and the coordination domain (time range about 8 to 15 seconds) might have been too small in comparison with the time recording for balance (up to one minute). We hypothesise that a larger number of cycles would probably have shown clear and statistically significant differences between developmentally impaired children and the control children.

In the present investigation, we studied differences between children with the ICD-10 diagnosis "expressive language disorder", "receptive language disorder", and "childhood autism". The results showed that the three groups of developmentally impaired children did not differ very much from each other with respect to the qualitative and the quantitative evaluation of the motor domains. There seemed to be an overall tendency of a greater impairment for the children with an expressive language disorder, whereas the children with a receptive language disorder and the children with autism seemed to have less impaired motor functions. As shown by the co-variance analysis, these differences could not be explained by age differences between the groups.

The scatter plot, however, showed that the motor performance of a small group of children with a receptive language disorder and a few children with autism was comparable to the motor performance of the control children. These results might suggest the existence of subgroups within the group of children with autism and children with a language impairment which cut across the ICD-10 classification. These data certainly need replication with comparable groups of developmentally impaired children but might indicate that the group of language impaired children and of autistic children as a whole is heterogeneous and that different subgroups with different aetiological factors have to be considered.

In this study, we found an increase in non-verbal deficits in a group of children with severe developmental impairments. These neuromotor deficits put an additional burden on the development of the children. As a matter of fact, anamnestic data revealed that two thirds of the children with autism and children with a specific language disorder had difficulties mastering daily routines such as eating properly with knife and fork, stair climbing, dressing alone, writing, playing with age-appropriate construction materials, ball games, bicycling. Many of these children had been involved in motor training programs or were still receiving such interventions at the time of the study. In autism, the occurrence of neuromotor deficits is taken as an indication of the importance of biological factors in the aetiology of the disorder [9, 12, 26]. Several authors stressed the relevance of motor problems as these deficits further impair the developmental course of the children [7, 10, 12]. Therefore, children with autism and children with a specific language disorder should be carefully screened for the presence of neuromotor deficits, in order for them to have the benefit of appropriate therapeutic interventions.

References

1. Amorosa H, Noterdaeme M (1992) Analysis of fine motor problems in children with specific developmental disorders of speech and language. In Integrative Biological Psychiatry. Emrich HM, Wiegand M (eds) Springer: Berlin, pp 61–69
2. Amorosa H, Scheimann G (1989) Sprechmotorische Defizite bei Kindern mit spezifischen Sprachentwicklungsstörungen. Sprache, Stimme, Gehör 13: 123–126
3. Bishop D, Edmundson A (1987) Specific language impairment as a maturational lag: evidence from data on language and motor development. Developmental Medicine and Child Neurology 29: 442–459

4. Ehlers S, Gillberg C (1993) The epidemiology of Asperger's syndrome. Journal of Child Psychology and Psychiatry and Allied Disciplines 34: 1327–1350
5. Ghaziuddin M, Butler E (1998) Clumsiness in autism and Asperger syndrome: a further report. Journal of Intellectual Disabilities Research 42:43–45
6. Grimm H, Schöler H (1978) Heidelberger Sprachentwicklungstest (HSET), Hogrefe: Göttingen
7. Hadders-Algra M, Touwen B (1992) Minor neurological dysfunction is more closely related to learning difficulties than to behavioral problems. Journal of Learning Disabilities 25:649–657
8. Hill E (1998) A dyspraxic deficit in specific language impairment and developmental coordination disorder? Evidence from hand and arm movement. Developmental Medicine and Child Neurology 40:388–395
9. Jones V, Prior P (1985) Motor imitation abilities and neurological signs in autistic children. Journal of Autism and Developmental Disorders 15:37–45
10. Kalverboer A (1993) Neurobehavioural relationships in children: new facts, new fictions. Journal of Human Development 34:169–177
11. Kaufman A, Kaufman N (1991) Kaufman Assessment Battery for Children (K-ABC) (Deutschsprachige Fassung von Melchers und Preuß). Hogrefe: Göttingen
12. Leary M, Hill D (1996) Moving on: autism and movement disturbance. Mental Retardation 14:39–53
13. Losse A, Henderson S, Elliman D, Hall D, Knight E, Jongmans M (1991) Clumsiness in children – do they grow out of it? A ten-year follow-up study. Developmental Medicine and Child Neurology 33:55–68
14. Maurer R, Damasio A (1982) Childhood Autism from the point of view of behavioural neurology. Journal of Autism and Developmental Disorders 12: 195–205
15. Mildenberger K, Noterdaeme M (1997) Entwicklungsneurologische Befunde bei sprachentwicklungsgestörten und sprachunauffälligen Grundschulkindern im Vergleich. Abstractband des XXV. Kongresses der Deutschen Gesellschaft für Kinder- und Jugendpsychiatrie und Psychotherapie, Dresden, p 54
16. Nass R, Gutman R (1997) Boys with Asperger's disorder, exceptional verbal intelligence, tics and clumsiness. Developmental Medicine and Child Neurology 39:691–695
17. Nickisch A (1988) Motorische Störungen bei Kindern mit verzögerter Sprachentwicklung. Folia Phoniatrica 40:147–152
18. Noterdaeme M, Amorosa H, Ploog M, Scheimann G (1988) Quantitative and qualitative aspects of associated movements in children with specific developmental speech and language disorders and in normal pre-school children. Journal of Human Movement Studies 15:151–167
19. Noterdaeme M, Schnöbel E, Amorosa H (1999) Neuromotorische Auffälligkeiten bei sprachentwicklungsgestörten Kindern. Sprache, Stimme, Gehör 3: 155–158
20. Ohrt B, Amorosa H, Bade S, Baude B, Breuer-Schaumann A, Castell R, Ehrenstein D, Gänshirt S, Mall W, Noterdaeme M, Schnöbel E, Tunpach M, Winnewisser M (1991) Studie zur entwicklungsneurologischen, kinderpsychiatrischen und neuropsychologischen Untersuchung von Schülern in sonderpädagogischen Diagnose- und Förderklassen. Abschlussbericht 1991
21. Powell R, Bishop D (1992) Clumsiness and perceptual problems in children with specific language impairment. Developmental Medicine and Child Neurology 34:755–765
22. Preis S, Schlittler P, Lenard HG (1997) Motor performance and handedness in children with developmental language disorders. Neuropediatrics 28:324–327
23. Rapin I (1996) Neurological examination. In: Rapin I (Ed) Clinics in Developmental Medicine No 139. Preschool Children with Inadequate Communication. Cambridge, Mac Keith Press, pp 98–122
24. Suchodoletz von W, Heiner A (1994) Motometrische Untersuchungen bei Kindern mit Sprachentwicklungsstörungen. Sprache, Stimme, Gehör 18:175–178
25. Touwen B (1982) Die Untersuchung von Kindern mit geringen neurologischen Funktionsstörungen. Thieme: Stuttgart
26. Tuchman RF (1996) Pervasive Developmental disorders: neurological perspectives. Review of Neurology 24: 1146–1150
27. World Health Organisation (1991) Internationale Klassifikation psychischer Störungen. ICD-10 Kapitel V (F). Dilling H, Mombour W, Schmidt MH. Huber: Bern