CASE STUDY

ACTA Vol. 12, No. 2, 2014, 215-235
NEUROPSYCHOLOGICA

Received: 01.12.2013
Accepted: 02.06.2014

A – Study Design
B – Data Collection
C – Statistical Analysis
D – Data Interpretation
E – Manuscript Preparation
F – Literature Search
G – Funds Collection

DOI: 10.5604/17307503.1111847

A REHABILITATION PROGRAM AND SELECTED TREATMENT METHODS FOR A CHILD SUFFERING FROM AGENESIS OF THE CORPUS CALLOSUM

Aleksandra Szulman-Wardal[1,2(A,B,C,D,E,F)], Arkadiusz Mański[3(A,B,C,D,E,F)], Paulina Pawlicka[1(A,B,D,E)]

[1] Institute of Psychology, University of Gdansk, Gdansk, Poland
[2] Kościerzyna Specialized Hospital, Kościerzyna, Poland
[3] Special Education Center, Kościerzyna, Poland

SUMMARY

Background: Children suffering from ACC, in the course of their development and growth, do not enjoy the same developmental chances as the healthy ones. Therefore the rehabilitation cannot be a series of accidental actions spreading over time, but should be given in comprehensive rehabilitation program. The aim of the study was to develop our tri-stage multidimensional and multidirectional rehabilitation program for a child suffering from ACC and evaluate this program in the clinical practice.

Case study: We will present a six-year long period of observation of the development of a child suffering from ACC treated with the use of our tri-stage multidimensional and multidirectional rehabilitation program. We will present the separate steps of rehabilitation procedure adapted to the needs of the child suffering from ACC.

Conclusions: The multidimensional and multidirectional rehabilitation program developed for a child suffering from agenesis of the corpus callosum was seemed to be effective.

Key words: dysgenesis of the corpus callosum (DCC), congenital defects of the central nervous system, developmental neuropsychology

INTRODUCTION

Agenesis/dysgenesis of the corpus callosum (ACC/DCC) is one of the most frequently occurring congenital malformations of the central nervous system. In the general population, it occurs with a frequency of between 3 and 7 cases per 1000, while among children suffering from abnormal psycho-motor development, the frequency may reach the level of 2-3 cases per 100 (Grozono, 1968; Kaczan & Śmigiel, 2012). ACC may occur as an isolated defect, or be accompanied by other disorders from a diverse clinical picture that includes several genetic syndromes. A search of two data bases for dysmorphologies (the Online Mendelian Inheritance in Man and the London Medical Database) shows, respectively, 231 and 420 genetic syndromes in which disordered development affecting the corpus callosum has been found. An extensive collation of selected genetic syndromes with ACC is provided, among others, by Halgren et al. (2011), Backx et al. (2011), Kaczan and Śmigiel (2012), and Jezela-Stanek et al. (2014).

Currently, it is possible to ascertain the cause of ACC in 30-45% of cases. The number of chromosomal aberrations in this group amounts to approximately 10%, whereas the presence of genetic syndromes is found in as many as 20-35%. The genetic etiology very often produces numerous malformations in an entire array of possible disorders. Malformations are changes caused by primary developmental disorders during the embryonic period. Referring to a certain abnormality as a malformation only indicates the period of time in which this defect occurs, and does not provide much information about the specific etiology of its onset. This differentiation may be of crucial practical significance for the rehabilitation of children suffering from malformations of the central nervous system. Malformations forming at the early stages of organogenesis are characterized by a higher level of complexity, and more serious results for the child's development. A different picture is presented by children suffering from malformations which occurred during later stages of morphogenesis. Children suffering from later malformations often develop normally, or the mild symptoms of malformation are conducive to the partial or complete compensation of the disorders (Goodman & Gorlin, 1983; Korniszewski, 1994).

The corpus callosum is a unique structure, not only because of its situation in the architecture of the encephalon, but also due to the accumulation of nerve fibres. The corpus callosum anatomically and functionally connects the two hemispheres of the brain, which makes it possible to ensure virtually unlimited transmission between them, using various media (Bochenek & Reicher, 1993). In terms of structures, two types of ACC are differentiated: type 1 and type 2. In type 1, the functional communication between the two hemispheres is not established, in spite of the anatomical presence of the fibers of the corpus callosum. The existing fibres gather along the medial parts of the hemispheres, forming the occipitofrontal fasciculi. This is a specific situation, caused by the disordered migration of the neurons, as a result of which the physical "transmission medium" exists, but there are no destination points which would make it possible for signals to reach the places where the integration of data should take place. In the case of type 2, the fibers of the corpus callosum are not formed, and there is no possibility of any processing of signals whatsoever (Probst, 1979; Kaczan & Śmigiel, 2012).

Identifying the origins of the problem often makes it possible to understand the core of the disorders more completely, and provides opportunities for prevention (if possible) and treatment. Familiarity with the etiology of ACC makes it possible to comprehend the nature of the disorders that affect a child suffering from ACC. The etiology is the starting point that determines the entire course of action to be taken in the case of a child with ACC (Szulman-Wardal & Mański, 2013).

CASE STUDY

Background of the patient and her family

AW's family situation has been positive, both in the course of pregnancy and currently. She is growing up in a two-parent family, in a rural environment, and is the youngest of four children, with two brothers and one sister. All three of AW's siblings are healthy. Both of the parents care for her with thoughtful attention. AW's mother did not work during her pregnancy. Currently, she remains unemployed, bringing up her children, in which she is assisted by her husband. AW's mother has a secondary education, and her father a vocational one.

When AW was born, her mother was 35 years old, and her father was 41. The birth of AW was not her parent's first experience of pregnancy and childbirth, and the previous ones had been entirely normal. Information obtained from the medical history indicates that the pregnancy had a normal course up to the eighth month. In the last month, it became necessary to admit the mother to hospital, and her stay there lasted until the delivery, for an interrupted period of 3 weeks. In the course of the pregnancy, the mother did not receive any medications. Both during the pregnancy and before, she did not smoke, nor has she ever drunk alcohol.

AW was born by means of a spontaneous delivery, and the pregnancy was carried to term. The position of the child was with her head up. She was not kept in an incubator, and was breast-fed from the very beginning. AW's post-natal status was unsatisfactory due to asphyxia. Gradually, her physiological parameters, as measured by the APGAR Score (Table 1), became stable.

AW's birth weight was 4600 g, and she was 62 cm long. The perimeter of the head was 39 cm, and that of the thorax was 35 cm. Upon leaving the hospital, her weight had increased to 4380 g. The stabilization of physiological functions did not progress spontaneously, because it became necessary to administer oxygen and medications, and also to use artificial ventilation.

Diagnosis

The foundation for effective rehabilitation is a comprehensive diagnosis. It is extremely important to look at the child not only in the synchronic perspective

Table 1. AW's APGAR Scores

APGAR indicators	Time of examination			
	1"	3"	5"	10"
Heart	1	1	2	2
Breath	0	0	0	2
Tonicity	0	0	1	2
Reflexes	0	1	1	2
Skin	1	1	1	1
TOTAL	2	3	5	9

(here and now), but also in the diachronic view (on into the future). The holistic perspective on the child, reaching beyond the current picture, is of enormous significance, at least in part because the child meets various specialists, who in many cases have little information about the previous status of this child.

In the course of our several-year-long observations of children with genetic syndromes and linked disorders, the authors have used primarily two diagnostic methods for examining a child: the DDST (Denver Development Screening Test) and the MFDR (Munich Functional Developmental Diagnosis). The Denver test is a screening technique, which, because of its accessibility, can be useful and usable even for individuals who do have a degree in psychology (for example, the child's parents, teachers, therapists, and other persons involved in rehabilitation). The Denver test includes four spheres of the child's functioning:

- the private-public sphere (PPS),
- the visual-motor coordination sphere (VMCS),
- the speech development sphere (SDS),
- the locomotion and posture control sphere (LPCS; Michałowicz & Ślęzak, 1982).

The Munich Functional Developmental Diagnosis (MFDR) is a much more complex method, and the prerequisites for its use include not only having psychological credentials, but also considerable experience in working with children. The MFDR makes it possible to estimate the developmental age of a child with great precision in the motor, mental, and social spheres. The MFDR is intended for use with children at an age of no more than seven years (Hellbrugge et al., 2013).

In observing AW's development in the course of rehabilitation, we took advantage of multiple checks with the Denver test. Figure 1 shows how AW was developing, in a diachronic perspective (up to age 6), and also in a synchronic perspective (PPSS, VCMS, SDS and LPCS).

In the period of AW's infancy and toddler years, none of the important abilities in the spheres we had selected for our research emerged when expected. The dysfunctions in the locomotion and posture control sphere (LPCS) were sufficiently disturbing to justify motor rehabilitation, in order to make it possible for

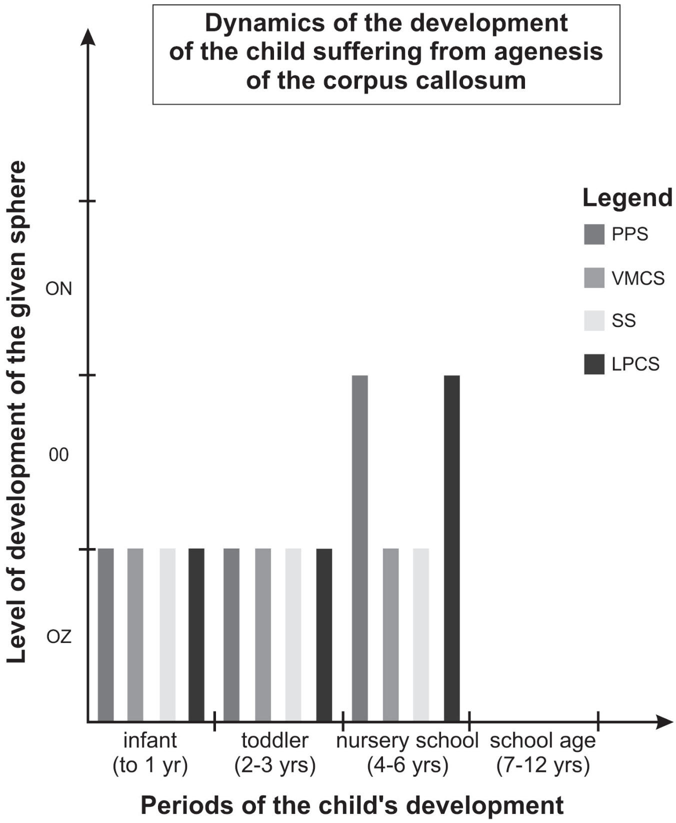


Fig. 1. Dynamics of the development of the child suffering from agenesis of the corpus callosum
Legend: PPS = the private-public sphere, VMCS = the visual-motor coordination sphere, SS = the speech sphere, LPCS = the locomotion and posture control sphere

AW to better perceive and explore her environment. Among the aspects of the LPCS, the following were indicated as urgent targets for developmental support:

- sitting;
- crawling on all fours,
- walking.

Intensive rehabilitation was aimed at AW reaching full competence in sitting by means of achieving confident balance in sitting up straight. The ability to crawl on all fours with cross-coordination turned out to be an intermediary link, and frequently an alternative one, also, in relation to walking, as a way of reaching various interesting places in space. Independent walking, which AW did not master until the beginning of the nursery-school period, made it possible for her to participate in activities in which she is accompanied by her peer group to a greater extent.

In the nursery-school period, AW's development became significantly differentiated in the analyzed functional spheres. It was only in that period that the strong and weak points of AW's functioning became noticeable. Clear progress was noticed in the private-public sphere, and also in the locomotion and posture control sphere. Previously passive and expecting help from her caregivers, AW became an individual capable of involving other people actively in her activities. The collapse of the symmetry of the research spheres, evidenced by the emergence of visible developmental symptoms concerning selected abilities, motivated us to modify her rehabilitation program. Specification of the strong and weak points of AW's functioning in the private-public sphere are presented in Table 2.

The picture of the strong and weak points of AW's functioning in the private-public sphere has been divided into:

- those abilities which are the foundation for independence;
- those which enable AW to observe the characteristics and behaviors of other people, and to react to them on the basis of the existing motor resources.

Since the very beginning of her rehabilitation, AW has been able to endear herself very quickly to the persons involved in her rehabilitation. Upon meeting her therapists, she first watched their movements and faces with attention, and then, after this period of slow and careful gathering of information, she came closer to them and gripped the therapist's hand, intending to come closer to a table or another functional object in the rehabilitation space. In respect to AW's social competences, it turned out that precise movements and the maturity of the perceptual apparatus are of major significance in the development of independence. This suggests that the basic source of her weak points in the PPS is not disturbed or disordered relationships in contacts with people, but rather disturbed development of precise motor skills, accompanied by visuo-motor coordination.

Hellbrugge et al. (2013), Halverson (1937) and Castner (1932) describe two crucial principles for shaping fine motor skills. The foundation for fine motor competence is the gripping movement, which develops in a direction from the largest muscles of the shoulders and arms towards ever smaller muscles of the wrist, thumb and index finger. The gripping movement is merely a more or less perfect tool, a stage on the road to the target, which may be gripping an object.

The development of AW's abilities in the VMCW and the domain of fine motor skills has been dominated, from the very beginning, by a nearly complete lack of any capability to use a mature grip and obtain information about small objects (Table 3).

Table 2. Specification of the strong and weak points of AW's functioning in the private-public sphere

Strong points	Weak points
expresses her needs; carefully observes her family members and friends, as well as therapists; participates in typical play; finds it easy to part with her family and friends; helps with simple housework; recognizes family and friends, and also strangers, adjusting her behavior accordingly; hands an object to a family member or a friend following a clear request or gesture; collaborates in dressing, eating and drinking, and also cleanliness activities and washing.	does not dress on her own; drinks from a mug held by someone else (with full movement programming); does not use a spoon or a fork on her own; washing hands requires the full involvement of persons around her; does not inform others of her physiological needs.

Table 3. Specification of the strong and weak points of AW's functioning in the visuo-motor coordination sphere and perception

Strong points	Weak points
grips objects with the entire hand, relocates them from one hand to the other, and puts objects away into vessels/containers; builds a tower of 2/4/8 blocks, also in interactional play with elements of alternating actions; can grip a few blocks simultaneously with her hand, and also hold certain objects in each hand for a longer time.	radial grip; drawing recognizable objects (for example figures, humans, houses, etc.); drawing lines oriented horizontally and/or vertically and in directions to the left or right; threading beads of various sizes; tearing paper in pieces by moving her hands in opposite directions; cutting out with scissors; forming non-spherical shapes of plasticine; placing basic geometrical figures inside insert puzzles; sorting figures according to selected criteria, such as color, size etc.

For AW, small objects are accessible only to the degree that enables her to have brief contact with a small part of the surface, when the hand touches the object and feels its texture. Very frequently, while gripping an object, AW immediately throws it down, enjoying the sound it makes when it hits the floor.

The SDS is perhaps the most puzzling aspect of AW's development. Against the background of the entire profile, in both the diachronic and synchronic perspective, this area of development remains the least differentiated zone. In a way, there is less to be said about speech than about the development of abilities in the other spheres. In spite of a strong desire to make contact with people, AW has so far failed to discover in other people (or in herself) this powerful tool of communication, language. In the SDS, we have observed an asymmetry in the scope of understanding speech and the ability to form utterances. The majority of significant sounds which AW has begun to utter are based on sensory-motor experiences. One example of this is a guttural sound that AW produces when she is holding something heavy in her hands. Many times, psychologists have noticed that the messages from AW become more legible for AW's milieu if they are resulting from the sensory experiences of motor behavior (Table 4).

The development of abilities in the LPCS shows the broadest scope of competencies. This picture is the most diversified one, and this tendency is strengthened in the course of rehabilitation. All the spectacular changes in AW's development occurred suddenly. In spite of the fact that individuals in her milieu

Table 4. Specification of the strong and weak points of AW's functioning in the speech sphere

Strong points	Weak points
reacts to the sound of her own name; reacts to scolding and praise; complies with simple commands; uses an onomatopoeia to indicate one picture of the two presented by the therapists; uses non-articulated sounds to express the experience of the heaviness of an object.	complete absence of active speech at the level of syllable, word, sentence etc.

Table 5. Specification of the strong and weak points of AW's functioning in the locomotion and posture control sphere

Strong points	Weak points
un-aided walking on flat surfaces; stable crawling on all fours; walking down and up the stairs using a 'child gait' holding the rail with one hand; sitting with full control over balance; walking, holding large objects with both hands; lifting large objects from the floor.	standing on one leg; jumping in place; jumping on one leg; walking down the stairs; walking backwards; walking foot behind foot forward and backwards; catching a bounced ball.

are convinced that AW would soon be crawling on all fours or walking, it was never possible to foresee even an approximate time frame for the emergence of these abilities. Perhaps the lack of the corpus callosum as a crucial structure in the functional architecture of the brain results in a change to the temporal order of the emergence of separate developmental achievements in terms of gross motor skills. In the course of rehabilitation, therapists noticed certain patterns. For example, neither the ability to crawl on all fours (earlier), nor to walk (later), enabled AW to reach various places in the environment – unless the surface on which she was moving was flat. No unevenness of the ground surface could be corrected by the nervous system in order to adapt motor behavior. Whenever she came across obstacles, AW turned her body towards the persons around her, so as to obtain their help and induce them to remove the obstacle. The motor programs involved in walking functioned only to the extent needed to be mobile on flat surfaces (Table 6).

REHABILITATION PROGRAM

Rehabilitation not only serves the objective of minimizing the functional losses incurred by a disabled individual, but also endeavors to strengthen the individual as far as the functioning of non-damaged structures is concerned (Heinemann, 2005; Bishop, 2005; Dykens, 2006; Kowalik, 2007). Positive rehabilitation psychology, by putting emphasis on the significance of non-damaged structures, opens up new pathways in the process of rehabilitation. The example of supporting the development of a child suffering from ACC also satisfies the postulates of positive rehabilitation psychology. In such a case, progress in the course of rehabilitation is determined by several factors, some of which are of primary importance. According to clinical observations, the parameters referred to below determine the prognosis for the development of children with similar types of developmental problems:

- the child's openness to the persons in their milieu;
- the presence (or absence) of perinatal complications;
- the timely occurrence of developmental events in respect to sitting, crawling on all fours, and walking.

These factors are also predictors of success in rehabilitation. The authors' observations show that it is possible to differentiate, essentially, two groups of children suffering from ACC, with positive and negative developmental prognoses in the course of rehabilitation:

- Good prognosis – the child experiences no difficulties in making contact with others, there were no perinatal complications, and the course of motor development in the period of infancy is normal and timely;
- Bad prognosis – the child suffers from disorders in making contact, there were perinatal complications, and the course of motor development has been abnormal from the beginning.

The environment of the ACC child, from the very beginning, should be a place filled with persons who have adopted an active attitude towards the child. If the child spontaneously reacts to people, then, in encounters with the environment that are valuable in psychological or social terms, impulses will be activated to draw the child closer in accordance with internal desires and needs. In the rehabilitation of a child with ACC, focus on the child as an individual who is also a part of the milieu constitutes one of the foundations for success in rehabilitation. In our model, the climate in the family environment constitutes the area in which rehabilitation begins, which means that all the persons who live close to the child become therapists as well. In an environment conducive to this, the child is merely a step away from discovering developmental impulses and the joy that stems from realizing intentions.

One of the areas in which development can take place is space, and larger movements are the means that enable the child to explore it. Gross motor skills, together with a wide scope of movements, make it possible for the child to reach individuals, places and objects in space. Movement is an expression of a desire, and the heterogeneity of the motor functions of the child makes expression possible, even if this sphere remains significantly disturbed. In the case of a child suffering from ACC and linked disorders, motor rehabilitation becomes a necessity, because it is the timely emergence of the ability to sit, crawl on all fours, and walk that makes it possible for children to fulfill their need to explore and investigate space in a safe way. Children with ACC, as soon as they discover the fact that they can move from place to place, become very active in terms of locomotion. When they have developed the ability to crawl on all fours, they move constantly, all through the halls, rooms or yards. The need to constantly stabilize objects in space is so strong that the child restlessly moves towards people and objects in order to push, touch, hug or lift them.

Dealing with extremely rare and unique genetic syndromes requires a certain kind of metaphorical perspective, due at least in part to the need to provide solid psychological grounding and meaningfulness for the work of rehabilitation. We have based our own model of rehabilitation for a child with ACC on the metaphor of a tree, in which the successful emergence of a fully grown crown is determined by the state of the root and the trunk. Children with ACC do not have the same developmental opportunities as do healthy children. The lack of developmental possibilities may be compared with the situation in which a tree has a root and a trunk, but there are no branches that could provide scaffolding – a frame to build on, and to deepen.

The rehabilitation of a child with ACC should take under consideration potential impact at three levels, arranged hierarchically (Fig. 2):

1. At the base level, exercises are directed towards the child acquiring full competence in the area of gross motor skills. Large movements make it possible to move in space. Also, due to the enormous number of variants in effectuation, they make a child's behavior more complex when the environment is not unidimensional (for example, the structural diversity of the surface). Gross motor skills make it possible to conquer space to the full extent of static and dynamic events; therefore, a certain minimum level of performance in this respect is a necessary but not sufficient condition for collecting experiences, which in the future will make it possible to gain more knowledge and more detailed information about objects and persons.
2. The next level reflected in our three-factor model is the space of actions on objects and persons. The hands and face become the crucial tool of cognition. Objects not only become more accessible to the child in a passive way (such as when the therapist places them into the child's hand, or hands the objects over to the child), but they may also serve the purpose of active manipulation in accordance with more or less complex motor skills (for example, a spoon can be gripped, used to touch the mouth, and then relocated to the other hand and put away inside the box). The complementary character of abilities in gross and fine motor skills is conducive to full expression; therefore, after gaining certain competencies in these areas, the child may express herself in many ways.

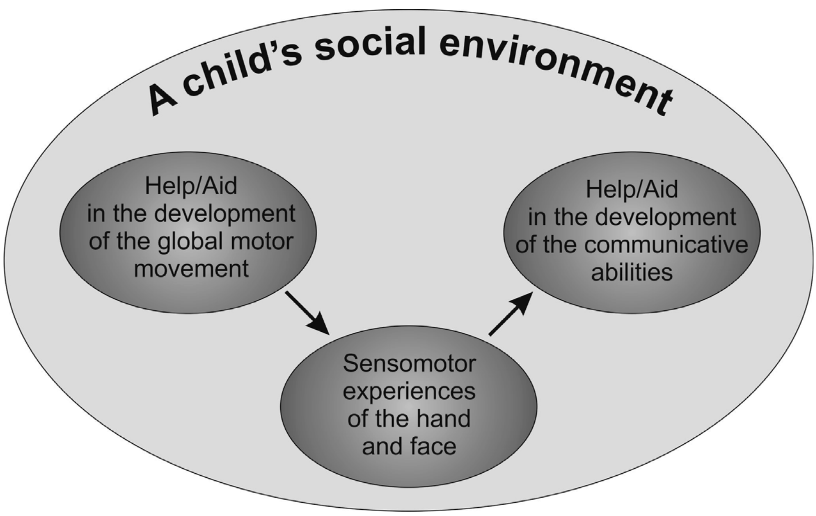


Fig. 2. Tri-stage multidimensional and multidirectional rehabilitation program

3. At the third level, communication becomes the dominant sphere in rehabilitation.

Tri-stage multidimensional and multidirectional rehabilitation program for a child with ACC is presented in Fig. 2.

A child suffering from ACC, regardless of the scope and depth of disability, needs exercises in which they will be successful through the interaction of both sides of the body. This principle results, first and foremost, from the structural and functional role which is fulfilled in development by the corpus callosum. At every level of the model presented here, the collaboration of both sides of the body can be a framework for inventive tasks and exercises. Familiarity with the structure and functions of the corpus callosum (the neuropsychological perspective), and also with the current picture of changes (the neurological perspective), supplemented by observation of the child's functioning, makes it possible to discover the most urgent and important objectives, so as to help the child feel joy as they travel along the paths of development. We are thoroughly convinced - and this belief is supported by the long-term observation of many children suffering from ACC/DCC – that the cohesion of rehabilitation with the established developmental course of a given capacity is of fundamental significance for a child suffering from ACC/DCC. Two spectacular examples are provided by us below, on the basis of research by Bruner (1978) into the development of the activity of reaching for objects under visual control and the capacity of using both hands in a complementary way (Table 6).

The development of the capacity to reach for objects under visual control progresses as a sequence of changes, the ultimate purpose of which is gathering

Table 6. The development of the capacity to reach for an object under visual control

Time of emergence	Picture of the capacity
4 – 5th month of life	The child ataxically reaches for an object. They can concentrate on a single object at a given moment.
6 – 8th month of life	The child is definitely able to better control the reaching movement. The presence of another object makes the child relocate the first one into the other hand. The child's concentration is no longer monopolized by one dominating object.
9 – 11th month of life	"Object storing" emerges, in every case preceded by relocating objects from one hand into the other.
12th month of life	"Object storing" becomes so absorbing that the child passionately accumulates (collects) objects; however, they are stored completely differently every time.
15 – 17th month of life	The child creates collections of objects consistently, and in a consistently repeated way.

Source: (Bruner 1978)

objects in an ever more complex structure. The impulse for this is the intention to grip, or even to master a fragment of the world that is attractive for the child. The persons involved in the rehabilitation of a child suffering from ACC/DCC, if they are familiar with the model course of the development of a given capacity, can determine the level at which the child is now, and the direction which further interventions should take, so as to obtain the greatest compatibility with the model of progress in the development of this capacity. Children suffering from ACC and linked disorders quite frequently display certain disturbances in the development of the capability to reach under visual control. Among other things, they drop objects, focusing on the sounds made when the object hits the floor or other surfaces; also, the need to put objects into their mouth persists longer than it should. These disturbances should not be extinguished directly. A look at them from the point of view of compensation strategies may make it easier for the therapist to reach the child and unblock natural developmental resources. When a child drops an object or throws it on the floor, wishing to hear a sound, then it is possible, by differentiating a set of objects and the textures of the ground, to learn more about the characteristic features of sounds attracting the child's attention. If the realm of sounds attracting attention is not diversified, we may extinguish this aspect (using a soft floor texture) or transform the will to throw an object anywhere into the ability to hit a target situated on the floor (a basket or a box).

Yet another problem may be the need to put objects into their mouth. Children want to get to know an object not only in a gustatory-olfactory dimension, but also in the kinesthetic one. In this aspect, particular significance is attributed to the face, which, at the sensory level, is the most sensitive part of the body. The direct elimination of the habit of putting objects into their mouth may be risky from the point of view of isolating the child from such an important way of learning about the world. There are many existing ways of getting round direct elimination. One of the more interesting ones, which also finds application in the case of children suffering from ACC, is stimulating the entire face or certain parts of it by applying objects that have differing sensory profiles.

The complementary use of both hands is the capacity that makes it possible to acquire objects whose location makes it impossible to grip them directly or reach for them using only one hand. The other hand is necessary, and participates in reaching the goal. The diverse picture of children's failures in this regard shows how this capacity develops, and its final stage is constituted by attempts to reach for the object with the use of both hands. Bruner (1978) indicates that ambidextrous efforts emerge suddenly, and not in the course of a gradual process of some kind. In research into children using a puzzle box, two groups of strategies leading to success or failure were differentiated (Table 7). Strategies based on the use of one hand to deal with a puzzle box nearly always lead to failure. A direct approach to the problem makes children create disturbances rather than grip an object hidden in the puzzle box (for example by scratching the curtain or hitting it), and these disturbances introduce a stimulus that diverts attention from the goal. Including ambidextrous forms in the task increases the probability that

Table 7. The most frequently observed forms of task performance using a puzzle box

PERFORMANCE/COMPLETION (using both hands)	FORMS OF FAILURE (using only one hand)
The child raises a lid with the use of both hands, or one of them, and then reaches for an object with one hand.	The child scratches or hits the glass shield. Hitting becomes an autonomous activity, diverting the child's attention from the conditions of the task.
From the beginning, the child stretches one hand out and raises the door, so as to reach for the object in the box with the other hand.	The child slides the door open and closed, without reaching for a toy. The action of manipulating the door becomes an autonomous determinant, diverting the child's attention from the goal.

Source: (Bruner 1978)

the object will be taken out of the box without generating accidental, attention-diverting disturbances.

Another source of experiences that can enhance the effectiveness of rehabilitation is holding large objects and manipulating them in space. Large objects can be gripped and relocated only with the use of both hands. Children suffering from ACC who have mastered the ability to walk can become interested in filling selected fragments of space with large objects in a very specific way. For a child, pushing, lifting, relocating and combining large objects into larger unities becomes the source of new motor and cognitive experiences. When the persons conducting the rehabilitation of a child with ACC notice this impulse in children under treatment, they can introduce new objects into the rehabilitation space. For several months, the authors and a child with ACC had been constructing figures made of four large geometric solids in the shape of a cylinder. The length of the cylinder was the same as the height of the child, and it was impossible to grip the geometric solid with only one hand. On her own and spontaneously, AW discovered cylinders in her environment and started constructing, which, in many cases, was creative. With considerable perseverance, she relocated the geometric solids from the floor onto the table, arranging them to form the shape of a raft. With a limited amount of advice from the therapist, she started arranging the geometric solids laterally, one next to another, to form a fence. Further advice directed AW towards a different spatial pattern. This way, an accidental discovery made by the child suggested interesting and creative development using large objects. Acting with the use of large objects, if preceded by the natural need to explore and reconstruct the environment, may be used by therapists in rehabilitation to differentiate between a strong grip and a precise grip in the child. On the basis of the theory that gross motor skills are the ground for the development of fine motor skills, therapists can place smaller and more attractive objects on larger ones, creating a situation in which the child, holding something large, has the opportunity to grip something smaller, not leaning the large object on the floor or on something else. This aspect of rehabilitation shows in a subtle way that children with ACC have to learn to control their body even when one hand is holding a large object, with considerable effort, and the other is simultaneously trying to grip a small object, attached to the larger one. This is another variation on the use of both hands in order to acquire an interesting object.

The rehabilitation of a child suffering from ACC requires a particular understanding of the child's situation, since, given their neurological resources, they do not possess a certain crucial structure guaranteeing the comprehensive functioning of the brain. The complete lack of the corpus callosum, when this is an isolated defect, makes it necessary to build new connections entirely on the basis of exercises and wise stimulation. In what follows, we present chosen rehabilitation aids, which may in an extremely interesting way support the actions of therapists involved in the rehabilitation of a child with ACC.

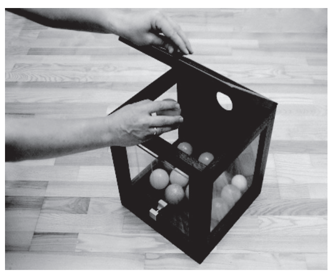
SELECTED AIDS FOR THE PROCESS OF REHABILITATION

Divergence box

The box is cubical, made of wood and a transparent plastic material (Fig. 3A). There are three ways to reach inside the box (orientation ʽtoʽ/Dyw=3*), but only two ways to remove objects (orientation ʽfromʽ/Dyw=2*). The box can be opened, and interesting objects can be taken out of it, in two ways. In the first case (Fig. 3B), the child uses one hand to lift the lid, and the other to reach inside. The construction of the lid makes it impossible to perform this task with only one hand. Each hand must complement the actions of the other in order to reach the goal.

In the second case (Fig. 4A), the child uses one hand to lift up transparent doors, and the other to reach inside for objects. As before, any attempt to use only one hand results in failure. There is also a third way (Fig. 4B), which we have called "uni-directional": it is possible to throw an object inside through a cir-

A)



B)

Fig. 3. Divergence boxes: A) general view of the box; B) the collaboration of both hands in opening the lid

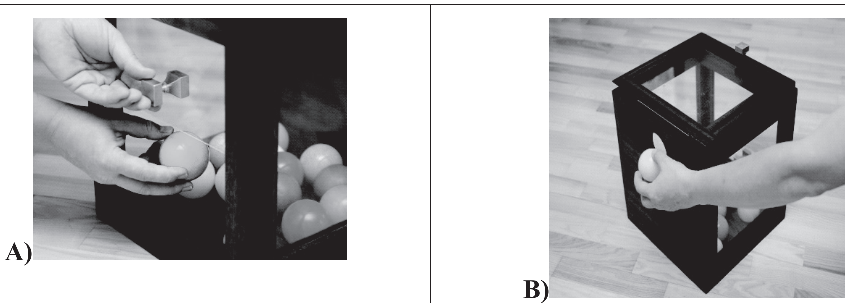


Fig. 4. The collaboration of both hands: A) one hand in opening up transparent doors and the other hand is reaching inside for objects; B) "uni-directional"way to throw an object inside through a circular hole in the back wall

cular hole in the back wall; however, taking it out this way is impossible even using both hands. The child must try to find another way in this situation.

Experts in the field of rehabilitation for children advise that rehabilitation have features of play. Therefore, playing with the divergence box (DB) makes it possible to produce experiences that divert children from direct reactions (at the beginning, children try to knock out, tear out, or jank open the doors with one hand). There are several paths leading to the goal, and at least one will always make it possible for the child to acquire the wanted object, which will ensure success, with its emotional rewards. One the other hand, in the executive dimension of tasks involving the box, the most important thing is for the child to discover an ambidextrous way of reaching for an object placed inside. The construction of the box itself already eliminates the possibility of acquiring the object directly, in spite of the fact that it is clearly visible through the transparent walls.

Here are a few examples of games played with the DB:

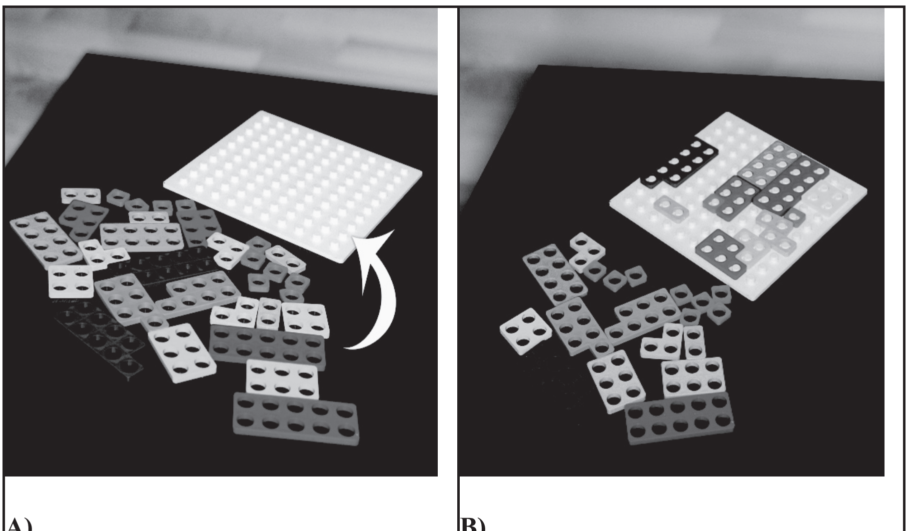
1. The therapist places in the DB an object which may be attractive for the child, and shows the child how to take this object out of the box using one of the two possible ways. Following the therapist's example, the child attempts to acquire the attractive object.
2. The child, with the help of a family member or a friend, makes a collection of colorful balls. The therapist makes the same collection, shows the child one ball, and asks the child to find a ball of the same color. Then, the therapist puts the ball inside the DB in a particular way, and asks the child to come closer to the DB and insert the ball in exactly the same way.
3. The therapist places a circle of a particular color on the plastic wall of the DB, and also blocks one of the pathways (for example, by placing a sticker over the hole in the back wall, or temporarily sticking the lid to the walls with plasticine, so as to make it impossible for the child to lift it). The child task's is to find in the collection a ball of the same color as the sticker. Afterwards, the therapist asks the child and a family member or a friend to come closer to the DB and insert the ball using the available pathway.

Numicon blocks

The Numicon system is a multisensory method for teaching how to count, used with normally developing children at nursery-school age, and also those starting school (Atkinson, Tacon & Wing, 1999, 2000, 2003). The idea of number inculcated by Numicon, pictured in the unique combination of a shape, color and texture, also serves to support the development of the ability to count, not only in the case of children developing normally, but also those suffering from Down syndrome and other disabilities (Freeman & Hodapp, 2000; Tacon, Atkinson & Wing, 2004; Nye, Buckley & Bird, 2005).

The Numicon material can be applied in the rehabilitation of a child suffering from ACC because the holes in the shapes of the blocks make it possible to grip them more firmly and reduce the risk of dropping. The blocks have a unique shape, since they are the combination of a certain number of very small squares. Numicon most frequently finds application in developing the ability to count; however, the material is constructed in such a way that, when Numicon is used, many educational ideas are reinforced, which frequently reach beyond the authors' originally intent. In their basic version, the blocks are complemented by a white board with convex parts that match the holes.

The simplest games that require the complementary use of both hands consist in placing a block on the child's fingers (Fig. 5 A), after which the child removes it using the other hand and places it on the board in any place (Fig. 5B). A block, once placed, does not move, and it is possible to fill in free space on the board in accordance with its shape.



A) B)

Fig. 5. The Numicon blocks: A) a blocks which are placed on the child's fingers, B) the child removes it using the other hand and places it on the board in any place

Balls

This rehabilitation device is composed of 15 wooden balls, and also a base with five numbered holes (Fig. 6). The balls may be put inside the holes, but they cannot be taken out with the hands. The only way is to lift the wooden base and throw the balls out of the device. The balls differ in color and texture. It is possible to construct 5 collections (each with a different number of balls) in which the balls will have the same color and texture. The balls are light and non-elastic. If thrown on the ground, they do not bounce back. The wooden base is always the target of games with the balls, and after a series of movements, the child finally puts the ball into an empty hole.

Exercises with the balls can be divided into two groups. In the first group, all the exercises take place near the child:

1. The therapist hides the ball in a certain item of the child's clothing (for example, in a sock). The child's eyes are covered, and they can only reach for the ball with the hand further from the place in which it is hidden. The child searches for the ball (for example using the left hand in the area surrounding the right feet) and, when it is taken out, places it on the wooden base.
2. The therapist puts the ball into a jar and closes it, then gives the jar to the child, suggesting that it needs to be opened, and that the ball needs to be taken out and placed in an empty hole of the wooden base.
3. The therapist puts some sand into a non-transparent bag, and then places a few objects (including a ball) into it. The child is encouraged to search the contents of the bag with one hand without visual control in order to find the ball and place it in one of the empty places remaining in the wooden base.
4. The therapist covers a ball with a thick layer of plasticine. The child is given the ball and shown how to remove the plasticine cover. When the entire cover has been removed, the child places the ball in the next-to-last empty hole.

Fig. 6. The rehabilitation device composed of 15 wooden balls which may be put inside a wooden base with five numbered holes

5. The therapist places a metal vessel at a certain distance from the wooden base. The child is given a wooden ball to be held in one hand, and a heavy metal ball to be held in the other; the metal ball is not very much larger than the wooden. Having two different balls with different properties, the child puts them in the right places. The wooden ball is to be placed in the last empty hole in the base, and the metal one in the vessel. The therapist should hand over the balls in such a way that the child can only place them with movements across the central line of the body.

In the second group, all the exercises are conducted within a larger space around the child:

1. The child, accompanied by a family member or a friend, sits at the table. Opposite, a therapist is seated with a ball. The therapist rolls the ball towards the child, so as to make them catch it with the hand situated opposite to the direction of the ball's movement. After catching the ball, the child places it in an empty hole of the wooden base.
2. The therapist puts a ball into a box. A small hook is screwed into the wall of the box, and a long, thin string is tied on the hook. The loose end of the string is given to the child. With the help of family members or friends, the child uses alternating movements to pull the box closer, then opens it and takes the ball out, placing it in an empty hole of the wooden base.
3. The therapist fastens a ball to the end of a string hanging over the child's head, or in front of the child's face. The ball is over the child's head, or at the level of their eyes. The therapist sets the ball in motion, and helps the child to catch it with one hand, without moving the body. When the child has caught the ball, it is unfastened and placed in an empty hole of the wooden base.
4. The therapist places the ball in the divergence box (DB) situated several meters from the child. The child comes closer to the DB and takes the ball out at their discretion, and, afterwards, comes back to their previous place and puts the ball into the penultimate empty hole.
5. The child, with a family member or a friend, comes closer to the therapist. The therapist gives the child two balls: metal and wooden. The child goes back to their previous position and places the wooden ball in the last hole of the wooden base, all the time holding the heavy metal ball in the other hand.

Rotary ball

The rotary ball is a structure unique from the point of view of rehabilitation. The ball is placed on a wooden column, around which it can rotate (either all of it together, or each of its four parts independently). On each of its four segements, in their spherical part, there are colorful marks (Fig. 7A). By performing appropriate rotations, it is possible to combine these parts in longer objects, even from the top pole of the ball to the bottom (Fig. 7B).

It is necessary to use both hands when acting on the ball in order to extend the single or parallel lines. The ball and its parts may also serve as a base for sticking on parts of figures, pictures or symbols. In the basic version, the child,

A) B)

Fig. 7. Rotary balls: A) A four segments, in their spherical part with the colorful marks; B) demonstration by the therapist appropriate rotations

using both hands, turns the parts of the ball in such a way that the colorful parts are displayed. In the more difficult versions, it is possible to stick the elements of a picture or a letter on the pieces of the ball, and the child, by manipulating (rotating) the ball, combines these elements, making them one object.

CONCLUSIONS

The rehabilitation of a child suffering from ACC/DCC cannot be a series of accidental actions spread out over time. The unusual etiological heterogeneity of ACC, however, makes it necessary to broaden the search for rehabilitation tools. T

he dysfunctions common to all children suffering from ACC/DCC result from the structure and functions of the corpus callosum. The proposal presented here is directly matched to the functions of the corpus callosum. In spite of the lack of the corpus callosum, or its underdevelopment, the functional integration that is provided by this structure in the functional architecture of the brain is made possible by finding alternative pathways (Brown & Pachalska 2003; Szulman-Wardal & Mański, 2013). Each and every achievement of a child suffering from ACC/DCC is a small step towards functional integration, or a direct result of complete integration. Functional integration takes place at three levels:

1. Motor integration, for achieving full control over the body when overcoming obstacles and travelling over distances in space, by the complementary use of both sides of the body.
2. Perceptive-Motor Integration, for achieving objectives that involve primarily the coordination of perceptive-motor functions by exercising the complementary use of both hands.
3. Communication-Linguistic Integration, for developing the ability to convey thoughts verbally and intentionally by the complementary use of various means of communication.

Each of these levels constitutes a separate target of rehabilitation, and the state of the corpus callosum may exert a significant influence upon its achievement; this fact should not be overlooked by specialists in planning the course of rehabilitation.

ACKNOWLEDGEMENTS

We would like to thank Manart Maciej Narkun (manart@op.pl) for helping us in preparation of this paper.

REFERENCES

Atkinson, R., Tacon, R. & Wing, T. (1999). Numicon: Foundation Book. Brighton, UK: Numicon, Inc.

Atkinson, R., Tacon, R. & Wing, T. (2000). Numicon: Year 1 Teachers Book. Brighton, UK: Numicon, Inc.

Atkinson, R., Tacon, R. & Wing, T. (2003). Numicon: Year 2 Teachers Book. Brighton, UK: Numicon, Inc.

Backx, L., Seuntjens, E., Devriendt, K., Vermeesch, J. & Van Esch, H. (2011). A balanced translocation t(6;14) (q25.3;q13.2) leading to reciprocal fusion transcripts in a patient with intellectual disability and agenesis of corpus callosum. Cytogenetic Genome Research, 132, 135-143.

Bishop, M. (2005). Quality of live and psychological adaptation to chronic illness and acquired disability: A conceptual and theoretical synthesis. Journal of Rehabilitation, 17, 5-13.

Bochenek, A. & Reicher, M. (1993). Anatomia człowieka. Warsaw: PZWL.

Brown J.W., Pąchalska M. (2003) The symptom and its significance in neuropsychology. *Acta Neuropsychologica.* 1(1):1-11

Bruner, J. (1978). Poza dostarczone informacje – studia z psychologii poznawania. Warsaw: Państwowe Wydawnictwo Naukowe.

Castner, B.M. (1932). The development of fine prehension in infancy. Genetic Psychology Monograph, 12, 105-193.

Dykens, E.M. (2006). Toward a positive psychology on mental retardation. American Journal of Orthopsychiatry, 76, 185-193.

Freeman, S.F.N. & Hodapp, R.M. (2000). Educating children with Down Syndrome – linking behavioral characteristics to promising intervention strategies. Down Syndrome Quarterly, 5(1), 1-9.

Goodman, R.M. & Gorlin, R.J. (1983). The malformed infant and child. New York: Oxford University Press.

Golden, J.A. (1999). Towards a greater understanding of the pathogenesis of holoprosencephaly. Brain & Development, 21, 513-21.

Halgren, C., Kjaergaard, S., Bak, M. et al. (2011). Corpus callosum abnormalities, intellectual disability, speech impairment, and autism in patients with haploinsufficiency of ARID1B. Clinical Genetics, 82, 248-255.

Halverson, H.M. (1937). Studies on the grasping responses in early infancy. Journal of Genetic Psychology, 51, 371.

Heinemann, A.W. (2005). Putting measurement in context: A rehabilitation psychology perspective. Rehabilitation Psychology, 50, 1-15.

Hellbrugge T., Lajosi F., Menara D., Schamberger R. & Rautenstrauch T. (2013). Monachijska Funkcjonalna Diagnostyka Rozwojowa. Pierwszy rok życia/Drugi i trzeci rok życia (3rd ed.). Wrocław: ATUT

Jezela-Stanek, A., Pelc, M. & Krajewska-Walasek, M. (2014). Mutacje genów kompleksu BAF jako nowy czynnik etiologiczny izolowanej oraz syndromicznej niepełnosprawności intelektualnej w zespołach Coffina i Siris oraz Nicolaidesa i Baraitsera. Pediatria Polska, 89(2), 112-124.

Kaczan, T. & Śmigiel, R. (2012). Wczesna interwencja i wspomaganie rozwoju u dzieci z chorobami genetycznymi. Cracow: Impuls.

Kowalik, S. (2007). Psychologia rehabilitacji. Warsaw: AiP.

Michałowicz, R. & Ślęzak, J. (1982). Choroby układu nerwowego dzieci i młodzieży. Warsaw: PWN.

Nussbaum, R.L., McInnes, R.R. & Willard, H.F. (2007). Genetics in Medicine (7th ed.). Philadelphia: W.B. Saunders.
Nye, J., Buckley, S. & Bird, G. (2005). Evaluating the Numicon system as a tool for teaching number skills to children with Down syndrome. Down Syndrome News & Update 5(1), 2-13.
Probst, E.P. (1979). The prosencephalies: morphology, neuroradiological appearance and differential diagnosis. Berlin: Springer-Verlag.
Szulman-Wardal, A. & Mański, A. (2014). Selected elements of the psychosocial functioning of a girl with holoprosencephaly. Acta Neuropsychologica, 12 (1) 103-113.
Tacon, R., Atkinson, R. & Wing, T. (2004). Learning about numbers with patterns: using structured visual imagery (Numicon) to teach arithmetic. London: BEAM Education.

Address for correspondence
Aleksandra Szulman-Wardal
Institute of Psychology,
University of Gdańsk
4, Bażyńskiego str.
80-952 Gdańsk, Poland
e-mail: psyasw@ug.edu.pl