Acalculia in patient with split-brain syndrome – a case study

(scientific paper)

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Abstract: *Aim of the contribution is to describe speech and language assessment and therapy of patient Jiří after removal of tumor in corpus callosum using a case study. Split-brain syndrome, cognitive impairment and acalculia occurred after tumor removal. Acalculia is an acquired disorder of processing and calculations skills following cerebral damage. Split-brain syndrome occurs in patients with damage to corpus callosum. Cognitive functions were assessed by an MoCA test and Addenbrook cognitive test, calculation was diagnosed by self-constructed test. After 1 month of therapy Jiří was retested using the same tests. Cognitive functions and calculation skills have improved however impairments in general numerical knowledge, place orientation and recent memory remained weak.*

Keywords: *acalculia, speech and language assessment, speech and language therapy, split-brain syndrome, recent memory*

1 Introduction

The aim of the contribution is to describe speech and language assessment and therapy of patient Jiří after removal of tumor. Neurorehabilitation was given by author of contribution (speech and language pathologist) in the Neurorehabilitation department of Faculty hospital in the Czech Republic. At the beginning of the hospitalization Jiří's cognitive functions, language and calculation were assessed. Based on the input assessment Jiří was given appropriate therapy. Cognitive functions, language and calculation were retested after approximately one month. After that Jiří was discharged to home care.

2 Theoretical basis

2.1 Acalculia

Number processing and calculation are an essential part of our culture: we use numbers for counting, measuring; we constantly need to calculate, understand fractions, proportions and ratios, and to understand and remember PIN codes, telephone numbers, addresses, shoe sizes etc. (Semenza et al., 2014). Acalculia is an acquired disorder of processing and calculations skills following cerebral damage (van Harskamp, Cipolotti, 2003). During the performing of calculations, parietal, prefrontal and cingulate areas are systematically activated (Dehaene et al., 2004). Activation of horizontal segment of the bilateral intraparietal sulcus (HIPS) is present solely during calculations and cannot be explained away by spatial, attentional, eye or finger movements artifacts (Simon et al., 2002). Eger (2003) and Naccache (2001) indicate, that HIPS is amodal and not specialized for a particular number notation: it reacts identically whether numerals are spoken and written, and whether they appear in Arabic notation or in spelled-out form. Left and right parietal cortices, therefore, showed a different resolution in single-digit comparison, the left being necessary for fine discrimination, and both right and left being able to support coarser comparisons (Ansari, 2008). Bilateral parietal lobes (intra-parietal sulci and neighbour areas, with an emphasis on the left hemisphere) is the neural substrate of number magnitude processing (ibid). Calculation ability represents a multifactorial skill, including verbal, spatial, memory and executive functions (Ardila, Rosselli, 2002). Acalculia is not a unitary disorder and can take a variety of different forms: patients may show impairments in number processing (number production and number comprehension), in calculation or both (Cappelletti, Cipolotti, 2012; Vitásková, 2013; Vitásková et al., 2015).

2.2 Split-brain syndrome

Split-brain syndrome (disconnection syndrome) occurs in patients with damage to corpus callosum e.g. in patients with multiple glioblastoma, after callosotomy and in patients with agenesis corpus callosum (Pekárková, 2015). In the case of split-brain syndrome information from the dominant hemisphere is not transmitted into motor area of the non-dominant hemisphere, so the dominant hemisphere loses control of the motor area of the non-dominant hemisphere (ibid.). Thus the corresponding side of body (mostly left hand) is not able to perform intentional and planned movements; however unintentional movements work well (ibid). Somatic and visual information from the left side of body and space is not transferred to their interpretative area and could not be used for reasoning and decision making (ibid). Patients could suffer from disturbed orientation in space and apraxia of left hand (ibid). Koukolík (2014)

states that disconnection of the hemispheres damage recalling information from memory whereas recognition is spared.

3 Research Methods

In the research part of the contribution we used the method of case study. For assessment acalculia we used our self-constructed test. Cognitive functions were diagnosed by Montreal Cognitive test (MoCA) (Nasreddine et al., 2005) and Addenbrook cognitive test (ACE-R).

3.1 Anamnesis of Jiří

Jiří is a right-handed 62-year-old man. He trained as a waiter. After he graduated from Hotel School he worked in his own restaurant, later as a taxi driver. His last job was a porter. Jiří likes going to his cottage, travelling, cooking and do-it-yourself activities around the cottage. He is interested in cars. He was after removal of tumor (anaplastic oligodendrogliom) with extension to ventricular system from front part of corpus callosum in 12th July 2017. Before, in February 2017 MRI showed subarachnoid hemorrhage with hematocephalus and small intracerebral hematoma in left gyrus rectus. He was hospitalized in the neurosurgery department, after in the neurorehabilitation department. After removal of the tumor, partial split-brain syndrome appeared. Jiří did not tactile recognize some items in his left hand, before he correctly named these items). On the 4th day after surgery Jiří tactile recognized 4 of 5 items in his left hand. He had severe troubles with recent memory. His psychomotor processing was slow. In the next 4 days Jiří produced rich speech in sentences. Naming was mildly impaired, sometimes he used semantic paraphasias. Comprehension of multiple instruction about pointing on different parts of his body was mildly impaired. In the next week, he could hold simple conversation, psychomotor processing remained slower, his recent memory remained severely impaired, but slightly improved. He was disorientated by place and time. He could repeat a sentence of up to 5 words. Jiří was placed into neurorehabilitation department 2 and half weeks after surgery.

4 Results

4.1 Input assessment

Results of assessment of calculation is in table 1, results of ACE-R is in the table 2 and results of MoCA test is in the table 3.

Table 1. *Results of Assessment of Calculation in Jiří.*

Task	Score on 3/8/2017	Score on 31/8/2017	Interpretation
1. Counting			normal
a) Forward (1–20) by one	20/20	20/20	
b) Backward (20–1) by one	20/20	20/20	
c) Forward (10–90) by tens	9/9	9/9	
2. Reading arabic numerals (up to 10)	10/10	10/10	normal
3. Personal numerical knowledge	5/5	5/5	normal
4. Transcoding			normal
a) Reading arabic numbers	7/7	7/7	
b) Writing arabic numbers	7/7	7/7	
c) Number words to arabic numbers	7/7	7/7	
d) Reading number words	7/7	7/7	
e) Verbal form to number words	7/7	7/7	
f) Arabic numbers to number words	7/7	7/7	
5. Mental calculations			improvement
a) +, –, *, / up to 10	7/8	8/8	
b) +, –, *, / up to 100	6/8	7/8	
c) +, –, *, / up to 1 000	12/16	15/16	
6. Subitizing	5/5	5/5	normal
7. Knowledge of arithmetic signs			normal
a) Reading arithmetic signs	4/4	4/4	
b) Completing arithmetic tasks with arithmetic signs	4/4	4/4	
8. Counting dots	3/3	3/3	normal
9. Numerosity judgement	9/10	10/10	improvement
10. General numerical knowledge	7/8	7/8	unchanging
11. Simple written calculation			normal
a) +, –, *, / up to 50	8/8	8/8	
b) +, –, *, / up to 1 000	8/8	8/8	
c) Calculations in columns	8/8	8/8	
12. Composition of value from money	7/7	7/7	normal
13. Number bisection task			improvement
a) Number bisection task	1/3	3/3	
b) True & false questions about number bisection	1/3	2/3	
14. Knowledge of arithmetic rules			deficient
a) Calculations with zero	7/8	8/8	
b) +, –	3/4	4/4	
c) *, /	1/4	2/4	
15. Story problems	6/7	7/7	improvement
Total	**213/232**	**226/232**	**improvement**

4.1.1 Assessment of calculation

Jiří's performance in counting, reading arabic numbers, personal numerical knowledge, transcoding, subitizing, knowledge of arithmetic signs, counting dots, simple written calculations and composition of value from money was correct and fast.

In single digit division (6 / 2) Jiří calculated for too long, approximately 2–3 minutes, as well as in subtraction (19–9, 76–42) and two-digit division (60/30). In simple division (72 / 8), two-digit subtraction (99–34), and two-digit multiplication (30 × 30) Jiří thought about the task so long that he forgot what to calculate.

One of 10 tasks of numerosity judgement was performed incorrectly (32 and 23).

In general numerical knowledge Jiří erroneously answered the question „how many legs does the housefly have", other answers were correct.

Jiří failed in half of the task of number bisection, all the tasks were presented orally, without number line (23 and 29, 32 and 38 and in the task if 84 is between 80 and 86 he thought too long – about 2 to 3 minutes). Tasks examining calculating with zero were performed flawlessly except task 5 /5 when Jiří answered 0 instead of 1. In the task concerning knowledge of arithmetic rules Jiří did not apply arithmetic rules, he tried to calculate tasks mentally (if 79 + 54 = 133 so 133 – 54 = ?, if 45 × 16 = 720 so 16 × 45 = ?, 84 × 5 = 420 and 83 × 5 = ?, if 63 × 4 = 252 so 63 + 63 + 63 + 63 = ?). In the other tasks eg. 37 + 19 = 56 and 370 + 190 = ? Jiří started to calculate two numbers around the word „and" without comprehension of the task. After examiner's notification he started to solve task correctly. In story problems there was an error in 1 of 7 story problems. In the multi – step story problem Jiří had a different result than he performed previously in the next calculation.

Table 2: *Performance of Jiří in ACE-R*

Areas of ACE-R	Score on 3/8/2017	Score on 31/8/2017	interpretation
attention and orientation	14/18	15/18	improvement
memory	10/26	14/26	improvement
verbal production	6/14	4/14	deterioration
language	26/26	26/26	normal
visual – spatial abilities	16/16	16/16	normal
total score	**72/100**	**75/100**	**improvement**

Table 3: *Performance of Jiří in MoCA test*

Areas of MoCA test	Score 3/8 2017	Score on 31/8 2017	interpretation
visuospatial orientation, Clock test	5/5	5/5	normal
naming of animals	3/3	3/3	normal
attention	5/6	5/6	unchanging

repeating sentences	1/2	1/2	unchanging
rapid naming	0/1	0/1	unchanging
abstraction	2/2	2/2	normal
memory – recalling words	0/5	0/5	unchanging
time and place orientation	3/6	4/6	improvement
total score	**19/30**	**20/30**	**improvement**

4.1.2 Assessment of cognitive functions and language by observation and by tests ACE-R and MoCA

Time and place orientation. Jiří could tell correctly actual date, day of week, year and season, he could not say actual month. He knew the region, state and town where he actually was, but he did not know the name of hospital or department or floor.

Memory. He was able to repeat 3 words from ACE-R test, but was able to recall only one word from 3 words after another task. Jiří could repeat 4 items of address from 7 items in ACE-R test. In the reminding remembered information, he could not recall any items in the ACE-R test as well as in the MoCA test. Hints given by examiner in the recognition of remembered address in the ACE-R test helped him in 2 items from 5. In subtest of long-term memory Jiří answered correctly 3 questions from 4. He did not know the name of the premier of the Czech Republic. Jiří did not remember when his girlfriend went him to visit the hospital. He did not remember of which disease his brother had died.

Attention and calculating. In sequential subtracting number 7 he made one error in the middle of the task in both tests. He made 2 mistakes in the indicating letter "A" in the MoCA test. Short form of digit span test in the MoCA test was solved well.

Language. His verbal production was slower, without anomic pauses or paraphases and fully meaningful. Naming was intact. Jiří repeated sentences from MoCA test with small inaccuracies. Comprehension of spoken and written language was good. Reading and writing was intact. In the rapid naming of the words Jiří could say 6 words beginning with the letter "p" in 1 minute and say 10 animals per 1 minute in the ACE – R test. In the MoCA test he produced 5 words beginning of letter "k" per 1 minute.

Visuospatial abilities. Jiří could copy pentagon, cube and block. Clock test was 100 % correct. A small part of trail making test in the MoCA test was performed very well. He could count dots and recognized incomplete letters in ACE-R test. But he is lost in orientation in the department of hospital. For example, he often went to the kitchen instead of bathroom. He went to watch TV to another department and floor of the hospital. He got lost in the area of hospital when he went to the snack bar.

4.2 Content of the therapy

The aim of the therapy was to improve vocabulary, cognitive functions, especially recent memory and calculation. Jiří had therapy from a speech and language patholo-

gist every working day. He was getting some assignments at every therapy. Sometimes he did not work on an assignment because he forgot that he had got some assignment. Family members were asked to encourage Jiří in the training.

For enlarging vocabulary he had to produce a maximum of words beginning with various letters, a maximum of words within 1 semantic category (e.g. brands of cars, drinks, meals, soups, means of transport, sports, clothes…), word game "verbal football", determining antonyms. Speech and language therapy was started with time and place orientation according to calendar, after with task focused on short term memory (for instance remembering 5 different songs, famous persons, shopping lists). Jiří was taught mnemonic devices – e.g. method of loci, categorization. After training recent memory, strengthening long-term memory and logical thinking followed – for example naming all members of Jiří's family, matching 2 foods that we can eat together, matching appropriate genus and species of mushrooms, completing idioms, thinking about mutual adjectives of 3 substantives. At the end of session information from training recent memory was recalled. Training of attention was carried out for instance by reading text backward. Training of calculation consisted tasks focused on mental calculations, numerosity judgement, number bisection task, knowledge of arithmetic rules and story problems. A personal diary was set up.

4.3 Output assessment

After approximately 1 month of training, Jiří was retested by MoCA test, Addenbrook cognitive test and test of acalculia. Results of these test are in the tables 1, 2 and 3.

4.3.1 Assessment of calculation

Jiří's performance in counting, reading arabic numbers, personal numerical knowledge, transcoding, subitizing, knowledge of arithmetic signs, counting dots, numerosity judgement, simple written calculations, composition of value from money, number bisection task, knowledge of arithmetic rules up to 10, knowledge of arithmetic rules in calculation with zero and in addition and subtraction and story problems was correct and fast.

In mental calculations up to 100 in the simple division (72 / 8) and in mental calculation up to 1000 in multiplication (30 × 30) Jiří still thought about answers too long.

In general numerical knowledge Jiří erroneously answered again in question "how many legs does the housefly have", other answers were correct.

Jiří failed only in one task in the second part of number bisection task– in the decision making if suggested number is between other 2 suggested numbers (if 78 is between 75 and 83 he said "yes".

In the task knowledge of arithmetic rules in the multiplication and division Jiří did not apply arithmetic rules and he mentally calculated the task in 45 × 16 = 720 so 16 × 45 = ?, 84 × 5 = 420 and 83 × 5 = ?.

4.3.2 Assessment of cognitive functions and language by observation and by tests ACE-R and MoCA

Time and place orientation. Jiří could tell correctly actual date, month, year and season, he could not say day of week. He knew the region, state and town where he actually was, but he did not know the name of hospital or department or floor.

Memory. He was able to repeat 3 words from ACE-R test, but was able to recall only 1 word from 3 words after another task. Jiří could repeat 6 items of address from 7 items in ACE-R test. In the reminding remembered information, he could not recall any items in the ACE-R test as well as in the MoCA test. Hints given by examiner in the recognition of remembered address in the ACE-R test helped him in 4 items from 5. In subtest of long-term memory Jiří answered correctly 3 questions from 4, he mixed up another question in contrast with input assessment. He forgot the name of president of the USA.

Attention and calculating. Jiří was successful in sequential subtracting number. He made 2 mistakes in the indicating letter "A" in the MoCA test. Short form of digit span test in the MoCA test was solved well.

Language. His verbal production was slower, without anomic pauses or paraphases and fully meaningful. Naming was intact. Jiří repeated sentences from MoCA test with small inaccuracies. Comprehension of spoken and written language was good. Reading and writing was intact. In the rapid naming of the words Jiří could say 5 words beginning with the letter "p" in 1 minute and say 7 animals per 1 minute in the ACE – R test. In the MoCA test he produced 4 words beginning with the letter "k" per 1 minute.

Visuospatial abilities. Jiří could copy pentagon, cube and block. Clock test was 100 % correct. A small part of trail making test in the MoCA test was performed very well. He could count dots and recognized incomplete letters in ACE-R test. His bad orientation in the department of the hospital remains.

5 Conclusion

Performance in counting, reading arabic numbers, personal numeric knowledge, transcoding, subitizing, knowledge of arithmetic signs, counting dots, simple written calculations, composition of value from money did not change. Jiří got better in the mental calculations, numerosity judgement, one part of number bisection task, knowledge of arithmetic rules up to 10 and in story problem, he did not make any mistakes. Jiří's answers with results in mental calculations was appreciably faster, unfortunately his 2 answers in mental calculations took time in some tasks. In general numerical knowledge Jiří failed in the same question. Jiří has troubles in mental subtraction and division, in the number bisection task which is also performed

mentally and in the knowledge of arithmetic rules. One wrong answer was present in the numerosity judgement, general numerical knowledge and in the story problems. The tendencies to calculate numbers around the word "and" in the task "knowledge of arithmetic rules" disappeared with another presentation of the task.

In time and place orientation and long term memory Jiří knew questions which he did not know in the input assessment and on the other hand he did not know questions which he knew before. Score remained unchanged. His ability to encode some information got better. Recalling remembered information was still poor, he had improved recognition of remembered information. Score in subtest attention in MoCA remained unchanged, however in subtest "Attention and calculation" Jiří scored one point more, so he successful solved the task, so attention is slightly improved. Despite training in vocabulary Jiří scored worse in producing words beginning with the letter "k" and "p" and producing maximum kinds of animals per 1 minute. Visuospatial abilities in tests stayed perfect. Orientation in the department of the hospital was still very weak.

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