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Izabela Gatkowska
Jagiellonian University in Krakow, the Faculty of Management and Social Communication, Department of Computational Linguistics
izabela.gatkowska@uj.edu.pl
ORCID:0000-0001-6126-3101

Olga Jauer-Niworowska
University of Warsaw, the Faculty of Polish Studies, the Institute of Applied Polish Studies
o.jauer-niworo@uw.edu.pl
ORCID: 0000-0001-8488-2933

Functioning of Lexical Connections in Patients with Neurodegenerative Diseases. Case Study of a Patient with Spinocerebellar Ataxia (SCA)

Abstract

Aim of the research: interdisciplinary description of functioning of lexical connections in a patient with spinocerebellar ataxia (SCA-type1). There is little research on lexical networks in patients with neurodegenerative diseases. Procedure: the subject was asked to give associations to 63 stimuli-lexemes. Tools used in the study: the *Experimental lexical network of the Polish language,* a digital recorder, an Olympus 650 DM. The *Experimental lexical network* was developed by Izabela Gatkowska (2017). It was created as a result of the study concerning the associations of 900 healthy Polish-speaking adults. Utterances of the subject were recorded, transcribed and compared with standard data. Results: the reactions of the subject were different from the associations presented in the *Experimental lexical network*. The most common verbal reactions were: creating definitions of stimuli-word meanings or making comment on them. Associations created by the subject were based on paradigmatic or syntagmatic relations. The authors explain how the specific verbal behaviour of the subject is related to the cognitive and language dysfunctions caused by the cerebellar damages. The results showed that language processing should not be regarded as separate from other cognitive functions. Verbal reactions of the subject are slightly similar to aphasic symptoms, but mostly they are related to cerebellar damage and executive disorders. The results obtained proved the validity of the connection between linguistic and psychological methods and tools in studies which concern the language behaviour of patients with neurodegenerative diseases.

Keywords: linguistics, psychology, experimental lexical network, speech-language disorders, rare neurodegenerative diseases, diagnosis, tools, methods, semantic disorders, cognitive disorders

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Introduction

The subject of this article is presentation of the part of research concerning lexical connections in patients suffering from neurodegenerative diseases. Neurodegenerative diseases are subject of interest in many branches of science: medicine, psychology, neuropsychology, linguistics, neurolinguistics. In neurodegenerative diseases we can observe increase of pathological changes. These changes result in disorders in many areas of functioning. In professional literature many neurodegenerative diseases are mentioned in which motor-speech disorders and language disorders can occur. Among them spinocerebellar ataxia can be listed (Silveri 2020). In the present article the authors describe the functioning of lexical connections in a patient with spinocerebellar ataxia-type -1. The present study is an element of current research into language semantic processing and the changes in the organization of the mental lexicon in pathological states.

The topic of the research is quite new, especially from the linguistic point of view, because the cerebellum is mostly associated with motor-speech disorders such ataxic dysarthria. Spinocerebellar ataxia is a rare disease (Dulski, Sułek, Sławek, Wszołek 2023). This is the reason of a little information about language functioning of patients suffering from this disease (selected important information about main symptoms of SCA are presented in next part of this article). It should be underlined as well that there is still little information about the role of the cerebellum in language processing. Research on the topic is ongoing.

The article has eight parts. At the beginning of this article the authors present crucial information about SCA, because symptoms of this disease are important for regulation of the language behaviour of the subject. In later sections they include theoretical – psychological and linguistic – frameworks of the present research. The authors share the idea of embodied mind (Varela *et. al.* 2017). According to this idea the brain is a dynamically changing system which regulates all human activity. The brain is shaped by biological (genetic), psychological (experiences) and social (interaction and communication) factors at the same time. Modern neuropsychological research however still has no detailed information about the role of many neural structures in process of regulating behaviours. In this situation researchers create models of brain activity and try to explain various human behaviours according to them. Language activity is one of the types of human behaviour which can be explained in terms of these models. Linguistic models of language functioning also refer to network models. One of these models is the Experimental lexical network created by Izabela Gatkowska. The experimental derivation of this model makes it possible to link the model to the psychological background of verbal responses. The approach combines theoretical approaches with experimental results. Linguistic behaviour is bio-psycho-socially conditioned.

The topic of the present study has a place within research concerning the mental lexicon seen as having a networked semantic structure. The study refers to a lexical network in which lexemes are semantically connected. The method used to elicit semantic associations has its basis in the way the mental lexicon functions in real life.

The main part of the text is a presentation of the study. It includes explanation of the methods (experimental presentation of verbal stimuli for the subject with SCA-type1). In the next part of this text, a description of disorders of language processing in the subject with cerebellar damage caused by SCA is presented. The last part of the text is devoted to explanation of the results of the present study and some conclusions.

Cooperation between neurolinguistic researchers and psychologists gives an opportunity to use the network models of language semantic connections in examining real language behaviour.

Interdisciplinary Framework of the Study Spinocerebellar Ataxia Symptoms – Selected Information from Medical Literature

Spinocerebellar ataxias are an etiologically heterogeneous group of diseases (Szczudlik, Rudzińska 2010; Sobów 2013; Dulski, Sułek, Sławek, Wszołek 2023); these authors underline that SCA is a rare neurodegenerative disease. It has an average frequency of 2-7 per 100 000 (Dulski, Sułek, Sławek, Wszołek 2023). There are more than 40 types of SCA. The most frequent type of the disease in the world is SCA-type 3, but in Poland the most frequent is SCA-type 1. Because of this**,** the authors of the present article have decided to focus on the subject of this type of SCA, and the description of this type of spinocerebellar ataxia will be more detailed than that of the other types.

The cause of the most types of SCAs is the mutation of the ATXN gene and the excessive CAG repeats in the fragments of DNA coding a protein called ataxin-1 (Szczudlik, Rudzińska 2010, Sobów 2013, Dulski, Sułek, Sławek, Wszołek 2023). The normal alleles contain from 6 to 39 CAG repeats, whereas the pathological range is from 41 to 83 repeats.[1]

The most frequently age of SCA-type 1 onset is the third or fourth decade of life (Szczudlik, Rudzińska 2010; Sobów 2013; Dulski, Sułek, Sławek, Wszołek 2023), but onset time of disease can be different in particular cases. It depends on the number of pathological CAG repeats. Patients with 40 to 50 CAG repeats tend to present initial symptoms in adulthood, while patients with more than 70 repeats present initial symptoms in teenage years. People who have about 35 CAG repeats do not present pathological symptoms, but their children are in the risk group of SCA-type 1.

In SCA we can observe a wide range of clinical symptoms, such as: gait ataxia, ataxia of the trunk and limbs, dysarthria, dysphagia, oculomotor disorders caused by cerebellar or supranuclear damage, spasticity, extrapyramidal disorders, senso-motor neuropathy, rare constrictor muscles disorders, disorders of cognitive functions in Polish patients with SCA (Dulski, Sułek, Sławek, Wszołek 2023). It should be stressed that cognitive disorders are quite frequent in SCA-type-1. Language disorders in patient with SCA can be observed as well (Jodzio 2011, 2020, D'Agata *et al.* 2011, Chrobak *et al*. 2014, Starowicz-Filip *et al.* 2017, Silveri 2020). These authors describe difficulties in updating words, grammatical competence, and semantic disorders, especially in comprehension of written text. These symptoms are similar to aphasic disorders and are called 'cerebellar aphasia'.

Other neuropsychological research has shown difficulties in attention, operative memory and executive functions, mood and emotional disorders, like depression, anxiety, irritability, agitation in patients with SCA as well (Visani *et al.* 2020). The neurophysiological MEG study[2] (Visani *et al.* 2020) showed that patients with SCAs have difficulties with 'Go No-Go' tasks engaging executive functions.

1 Information about the genetic disorders is taken from the Home Page for the Center for Medical Genetics "Genesis" https://www.genesis.pl/study/atxn1 [date of access: 17 February 2021].

2 There are two main Neuroimaging techniques used in scientific studies. The fMRI technique can monitor the activity of the whole brain simultaneously. It detects hemodynamic and metabolic responses from many regions of the brain, including

The present paper describes the influence of cerebellar damage on language processing in one particular patient suffering from SCA-type 1. The article provides new information about this problem, because the results of the research, which are presented in the further part of this text, are partly unexpected for the authors and can shed new light on connections between language processing and other cognitive functions. The description of the results of the study is presented in further part of this text.

Psycholinguistic Models of Language Processing

There are various points of view referring to interdependencies and involvement of the brain in cognitive activities, including language processing. Some researchers (*e.g.*, Friederici 2006; Shalom, Poeppel 2008) see the language as a distinct component in the brain, whereas others (Hagoort 2005) emphasize that language cannot be perceived as independent from non-verbal functions.

The first point of view is based on the connective theory of the brain functions. According to this theory there are domain-specific modules associated with different language functions (*e.g.*, syntactic, semantic etc.). The most famous model within this point of view is Hickok and Poeppel's model. These authors wrote about two streams — ventral and dorsal. These streams are called the "what" stream and the "where" stream respectively. The former processes language comprehension and the latter transfers auditory information to motor language response (articulation of verbal sounds). Friederici and Makuuchi (Friederici 2006, Makuuchi; Friederici 2013) proposed similar, but a more developed model. Makuuchi and Friederici (2013) include the working memory in their model of cortical language processing. In Hickok and Poeppel's (2008) and in Makuuchi, Friederici's (2013) models the brain is perceived as the system of functionally specified modules which cooperate through multi-level and reciprocal connections of these modules.

Hagoort (2005) presented an alternative point of view according to which language processing engages distributed neural networks. Hagoort argued that both language comprehension and production engage distributed neural networks at the same time. Language processing of auditory data and verbal motor response happen parallelly. Price (2012) underlined the role of non-linguistic components in language processing. She underlines the role auditory and visual processing in semantic processing and articulation. The similar point of view is shared by Maria Pąchalska, Bożydar Kaczmarek and Juri D. Kropotov (2014). These authors underline that language processing cannot be viewed separately from non-verbal cognitive functions.

Studies of the last 15 years (Bonelli, Cummings 2007; David 2011 *et al.*) highlight involvement of the subcortical structures (such as thalamocortical loops and basal ganglia) in regulation of cognitive functions and language processing. These structures are activated among others in implicit language processing (Conway, Pisoni 2008). The modern neuroimaging studies also provide evidence of the role

cerebellum. It is also used to examine the involvement of the cerebellum in potential large-scale cerebral networks. This tool however has a severe limitation when it comes to investigating the precise temporal properties of neural structures activity (Diedrichsen *et al.* 2019). Electrophysiological techniques, namely EEG, MEG, are more precise in temporal properties registration. They can register and compare the activation of cerebellar structures and other regions of neural networks in the brain with millisecond range (Andersen *et al.* 2020). In longer period of time, (related to fMRI studies), the activation of distributed networks of the brain is showed, however, in shorter perspective, (registered by EEG, MEG), continuous dynamic changes in electrochemical activation of various areas of the brain are noticed.

of cerebellar-thalamocortical pathways in cognitive and language functions (Diedrichsen *et al.* 2019). The cerebellum according to modern research is considered a structure which takes part in regulating attention, emotional behaviour and motor behaviour (Jacobi *et al.* 2021) thanks for specific feedforward and feedback connections between cerebral cortex and associative and motor cortical areas.

It is also well-known that significant individual variability in brain activation can be observed. That applies both to healthy subjects and patients with various brain impairments.

The literature review we have presented shows that, on the one hand, there are indeed general regions of the brain connected with language comprehension (the posterior sensory language area engaging mainly the temporal cortex) and production (the anterior motor language area traditionally associated with the frontal cortex). On the other hand, however**,** we can see the parallel activation of both these regions during the speech movements observation (Fridriksson *et al.* 2008).

The authors of this article share the view that language processing needs simultaneous activation and synchronic cooperation between neural networks regulating production and comprehension of speech, including cortical, subcortical and cerebellar structures.

Experimental Lexical Network as a Useful Tool in the Present Study

The study which is the subject of this article illustrates connection**s** between semantic processing disorders and cerebellar damages in the patient with SCA. This is within the scope of mental lexicon investigation**s**. There are two main topics of mental lexicon research. One of them is focused on the first or the second language acquisition (De Anda, Poulin-Dubois, Zesiger, Friend 2016) and the second concerns pathological changes in the mental lexicon in patients with various neurological/psychological impairments (Castro, Stella 2019). The present study is consistent with the latter. Linguists describe language changes using network models of mental lexicon. The preview of professional literature illustrates three major types of these network models — simple networks, connectionist networks, complex networks (McCarthy, Mirapleix 2020).

Simple networks were used in early research. They illustrate arbitrary structure of mental lexicon and its hierarchical structure (Evans 2006). This type of network can be used to explain individual language processing (*e.g.,* understanding decomposable phraseologisms through connections between the meaning of their components and the appropriate visual associations). The framework of this model is cognitive linguistics. The connectionist networks are described in 50% of linguistic research, which concern mental lexicon, especially in computational linguistics. This type of networks is useful in investigation of structure of the lexical networks in the mind and in analysis of their features (Elman 1991, Wilks, Meara 2002, Li, Farkas, Mac Whinney 2004, Li, Zhao, Mac Whinney 2007, Vitevitch, Goldstein, Siew, Castro 2014). These networks are helpful when explaining such intricacies as lexical network density, nodal spreading activation, ability to self-organize the lexicon in the processes of language acquisition. Using these networks, researchers can show quantitative dependencies between words of the lexicon, *e.g.*, the strength of lexical connections in semantic memory.

There are two main types of connectionist networks: localist and distributed networks. In the former, a node represents a singular concept.

In contrast, in distributed network a node shares concept. The connectionist networks are different from complex networks (McCarthy, Mirapleix 2020).

Complex network gives wider possibilities to explore and explain language organization in the mind and in the brain. Complex networks can be used in interdisciplinary research. They use mathematical language to illustrate various phenomena in society and human behaviour — the structure of mental lexicon and language processing, among others. They can be used in research concerning both individual language behaviour (they refer to psycholinguistic analysis) and global linguistic problems (such as co-dependency of mental lexicons of different languages in multilingual people). This mathematical analysis enables illustrating network density, length of the pathways from one node to another and the strength of connections between words, frequency of the words in the lexical network.

In modern research there are two methods of creating models of mental lexicon. The empirical approach based on language knowledge and intuition of linguists and analysis of texts based on artificial intelligence. The authors of the present article used empirical approach. The authors have decided to use the experimental lexical network as a tool to detect the semantic memory and attentive processing disorders caused by organic damages (Castro, Stella 2019). This tool had been prepared by Izabela Gatkowska (2017). This is a complex lexical network. It illustrates the strength, quality, density and direction of connections between the words in lexical network.

The Method of Obtaining the Experimental Lexical Network Used as a Tool in the Present Study

This tool has been obtained in the course of an experiment conducted by Gatkowska in the years 2011–2014. Nine hundred (900) university students from the Jagiellonian University and the AGH Academy of Mining and Metallurgy in Cracow have participated in this experiment. They were native speakers of Polish, who came from all over Poland, and various social milieus, and who had various majors. Their age group was 19–24. There were no students who were majoring in philology or psychology, as their knowledge of language could have possibly influenced the test results. On the basis of data originating from the association tests for English, we know that the age (see: Kent-Rosanoff 1910) and education (see: Russell 1970, Palermo, Jenkins 1964, Kiss, Armstrong, Millory, Piper 1973) of the participants is not crucial to the results of the experiment. Thus, the lexical network which was created during this study provides reliable information about the dependencies between lexemes in the lexical system of the Polish language. The experiment was conducted under controlled conditions. The research was anonymous, and participants were required only to state their age and sex.

The study had been conducted in two cycles. The participants had created verbal associations after short (5 seconds) presentation of the stimuli-words on the computer screen.

This time limit is based on the results on psychological studies of verbal fluency (Szepietowska, Gawda 2011). They illustrate that 5-second time limit is long enough to create at least 1 verbal association. The experiment with the time limit had enforced the participants to give the first association which had been obtained after presenting and understanding the stimulus-word. The list of the 63 words had been created in the first cycle of the examination. Grammatically, stimuli-lexemes were nouns. In the second cycle, the association-words from the first cycle served as stimuli-words. As a result of this experiment, in

which 322 stimuli were employed (63 in the first phase, and 259 in the second), a network was obtained. In this network there are: 10 448 lexical nodes (dictionary entries) as well as 35 170 links between the nodes. These data had been obtained after removing proper names, i.e., *city -Warsaw, river – Vistula*, and phrases i.e., *hut – outside of the village*, *uncle – Tom*, responses which were misspelled and copied responses, which appeared as responses to the 322 stimuli.

As a result of this analysis, it may be stated that a lexical node network is formed by:

- Nouns – 69 %
- Adjectives – 22 %
- Verbs – 7 %
- the remaining Parts of Speech (pronouns, numerals, adverbs and uninflected parts of speech) form only – 2% of the nodes in the lexical network

The lexical structure of the nodes has its counterpart in the structure of the links between the lexemes in the network. These links could have been observed between nouns, verbs, and adjectives. They constitute as much as 96.5% of all the links in the network. These results show that 63% are nouns, 4.3% are verbs, and adjectives are 29.2% of the links. The remaining parts of speech and proper nouns make only 3.5% of all the links in the network, which means that pronouns are 0.61%, adverbs are 0.25%, uninflected parts of speech (prepositions, conjunctions, particles, etc.) are 0.24%, proper names – 0.9%, and expressions – 1.52%.

The Quality of Connections in the Network - the Determinants of Quality

Our research on the lexical system cannot be limited to statistical and grammar analysis.

The research on the essence into a lexical system demands the construction of tools which can be used to interpret the quality of links between nodes in the experimental network.

In the monograph (Gatkowska 2017), Deese's (1965) view was adopted that the set of stimulus-response connections determines the meaning of the stimulus lexeme, which makes it possible to treat the lexical network as an experimentally constructed dictionary. From the point of view of network description, it was necessary to adopt an appropriate formal model of paradigmatic lexical relations that would organize the structure of the dictionary (*i.e.* hyponymy, meronymy, synonymy, antonymy and complementarity) as well as causality.

Syntagmatic relations occur equally often and build meaning (Gatkowska 2021; Gatkowska, Arias Navarro 2022). Syntagmatic relationships have been identified and described. A complete list has been published in the monograph by one of the authors of the present text (Gatkowska, 2017). This is explained in detail in the monograph. Similarly, the monograph explains the dependencies, the terms of which are included in this article.

In the present study the authors used the list of 63 stimuli-words which had already previously been used in the first cycle of the study conducted in 2011–2014 by Izabela Gatkowska.

The Description of the Present Research

Thesis of the present study

On the basis of medical and neuropsychological literature (Jodzio 2011, 2020, D'Agata *et al.* 2011, Chrobak *et al.* 2014, Starowicz-Filip *et al.* 2017, Silveri 2020) the authors of the present study formulate the thesis that the cerebellar disorders can be a cause of difficulties in updating of words, grammatical competence, and semantic disorders.

Information about the Subject

The subject of the research was a 46-year-old patient with SCA-type 1. The symptoms of the disease had been observed for 18 months. He presented gait symptoms and discoordination of precise movements of limbs. He did not complain about extrapyramidal symptoms, such as dystonia. During the whole study he was able to cooperate with the researcher and he was in a good mood. The researcher, who was in the direct contact with the subject, did not observe any symptoms of depression. The subject has occupational education. Before the symptoms appeared, he had performed active military service in the Navy, then he had worked as a butcher. He is married and has a daughter. The authors had not asked the subject about his interests and the way he spent his free time. He was psychologically assessed using the Raven Matrix Standard Test (Jaworowska, Szustrowa 2000). The score in this test was 52 centiles. This result indicated that the intellectual level of the subject remains normal.

Information about Research Methods

The study proper consisted in creating lexical associations after presenting the words from the list of stimuli-words mentioned above.

The lexemes-stimuli, which were used in the present study, were semantically variable. There were the names of: people, parts of the body, emotions, physical conditions (for example health, a disease), animals (for example a lion, a spider), plants (for example a flower), various parts of plant (for example a stem), specific objects (a hammer, a needle, a house, a table, a lamp), abstracts (for example justice, religion, music), products of nature (for example a mountain, a river), natural phenomena (for example light). They were emotionally neutral from the linguistic point of view.

The authors are aware that interpretation of emotional load of the words differs in psychological and linguistic research. Psychologists tend to refer to words as emotionally marked when meaning of words is connected to emotionally significant experiences of speaker. In contrast, linguists focus on dictionary meanings of words. For instance, the word "book" could be interpreted as emotionally positively marked by psychologists while linguists would mark it neutral. The authors have decided to adopt the linguistic point of view in the interpretation of the meaning due to the fact that the emotional preferences of the subject remain unknown.

The subject was presented with consecutive stimuli-words on the computer screen. The associative task in this study had no time limits. This method of the examination resulted from the specific ways in

which an SCA subject has functioning; there is a distinct decrease of verbal fluency. Imposing a time-limit could result in a shortage or even a complete lack of verbal reactions falling within the limit.

The subject was asked to give verbal associations for every word presented to him. When the subject notified that he could not give any more associations, the researcher switched the screen to move on to the next word.

Utterances of the subject were recorded on the digital recorder (Olympus 650 DM), written down and analyzed. A linguistic and psychological analysis of these utterances was then conducted.

Lexical associations elicited were analyzed to check:

- compatibility of the lexical reactions with normal associations (standard) to indicate the reactions, which were different than normal.
- compatibility of the reactions of the subject with the directions of the researcher.

Assessment of compatibility of verbal reactions of the subject with normal verbal behavior gave the information about severity of language disorders. It gave information about language and communicative skills of the subject, which are dependent on his cognitive and executive functions (visual and hearing perception, attention, verbal thinking).

Registration of verbal associations number is also an important aspect of the data analysis. Referring to the psychological professional literature, the researchers registered reactions with a single associative-word after the stimuli-words presentation. This is a symptom of disorders in word selection.

Description of language difficulties of the subject is based on detailed qualitative and quantitative analysis of his verbal associations.

Results

Healthy people in the earlier study (standard) had given associations which can be explained by paradigmatic or syntagmatic semantic relations. When healthy participants had had difficulties with understanding the stimulus-word's meaning, they had asked the researcher "What is this?", (in few cases).

Linguistic Analysis

Analysis of the most common standard associations.

We can classify the stimulus-response relationship qualitatively as lexical dependencies (regardless of the direction of the lexical relationship, Gatkowska 2017:48–51), in the first position we list the stimulus and the second most common answer to it. Original examples from the study in Polish in parentheses.

Lexical relations:

We explain and give examples of the strongest answers in the standard.

1. **paradigmatic relations** such as:

a. hyponymy (hiponimia), we adopt the definition of the hyponymy J. Lyons (1968: 453), based on the model of intension and extension (Gatkowska 2017: 51–53),

for example: fruit: an apple (owoc: jabłko), spider: garden spider (pająk: krzyżak), music: jazz (muzyka:jazz), earth: planet (Ziemia: planeta), vodka: alcohol (wódka: alkohol), eagle:

bird (orzeł: ptak), thief: pickpocket (złodziej: kieszonkowiec), joy: happy (radość: szczęście), king: ruler (król: władca), muton: meat (baranina: mięso), eagle: bird (orzeł: ptak), baby: child (niemowlę: dziecko), affair: fear (obawa: strach), hand: leg (ręka: noga),

b. meronymy (meronimia), we derive the study of meronymy from collection theory (mereology), a logical model of a set using one part-whole relation and distinguishing various types of a whole (Gatkowska 2017: 53–58),

for example: river: water (rzeka: woda), window: pane (okno: szyba), leg :foot (noga: stopa), soldier: army (żołnierz: armia), stem: flower (łodyga: kwiat), bread: food (chleb: jedzenie), Bible: tome (Biblia: księga), ocean: water (ocean: woda), tobacco: cigarette (tytoń: papieros), salt: pepper (sól: pieprz)

c. synonymy (synonimia), is the relationship between the meanings of lexemes that have identical or similar meanings in a given context (Gatkowska 2017: 58),

for example: doctor: physician (doktor: lekarz), religion: faith (religia: wiara), trouble: problem (kłopot, problem),

d. antonymy (antonimia), the relationship between objects, states, or actions whose meanings are opposite in a given context (Gatkowska 2017: 58),

for example: health: sickness (zdrowie: choroba),

e. complementarity (komplementarność), the relationship between naturally related objects or states whose meanings are mutually exclusive (Gatkowska 2017: 58),

for example: woman: man (kobieta: mężczyzna), man: woman (mężczyzna: kobieta),

2. **syntagmatic relations,** such as:

a. set (komplet), defines the relationship between things that share a common destiny intended purpose; usually one of the things brings additional features to be increase the usefulness of things for their intended purpose (Gatkowska 2017: 65),

for example: table: chair (stół: krzesło); table: chair (stół: krzesło) needle: thread (igła: nitka), hammer: nail (młotek: gwóźdź),

b. location (lokalizacja), defines the spatial relations between objects (plants, natural objects, artifacts); the relation is relative we have a locating and locating object (Gatkowska 2017: 66),

for example: justice: court (sprawiedliwość: sąd), memory: brain (pamięć: głowa) head: pains (głowa: boli),

c. intensity (intensywność), determines the relationship between a state, situation, action, event or phenomenon and a state that determines the subjectively perceived degree of severity of a state, situation, action or event (Gatkowska 2017: 66),

for example: working: heavy (praca: ciężka),

d. specific property (właściwość swoista), determines the relationship between: people, animals, natural objects or artifacts (things) and states or actions that define the specificity of the object (Gatkowska 2017: 62),

for example: cabbage: pickled (kapusta: kiszona),

e. sign (oznaka), determines the relationship between hidden (non-perceptible) states, feelings and perceived signals [symptoms] of their existence represented by another state or action, (Gatkowska 2017: 66),

for example: sickness: pain (choroba: ból),

f. source (źródło), it occurs between objects (people, animals, plants, natural objects, phenomena, things or characteristic places) and abstract things, phenomena or artifacts; it indicates where something came from, where it originated or from what it was obtained (Gatkowska 2017: 65),

for example: lamp: light (lampa: światło), light: lamp (światło: lampa),

g. size (rozmiar), defines the relationship between: people, animals, inanimate beings including natural objects and artifacts (things) and the physical features of the object, determining the perceived (relative) or measured (absolute) physical dimension (Gatkowska 2017: 61),

for example: boy: little (chłopiec: mały), child: little (dziecko: małe), street: long (ulica: długa),

h. taste (smak), determines the relationship between: people, animals, natural objects and artifacts (things) and the properties perceived through the sense of taste, can take on taste values (Gatkowska 2017: 62),

for example: food: good (jedzenie: dobre),

i. purpose (przeznaczenie), determines the relationship between objects (things, works, abstract artifacts) and actions expressing the reason why a thing was done (or made) or exists, means: what the object is for (Gatkowska 2017: 64),

for example: bed: sleep (łóżko: sen), scissors: cut (nożyczki: ciąć),

j. temporal location (lokalizacja w czasie), determines the relationship between animate objects, inanimate objects and abstract states or artifacts (hour, day, month), constituting time definitions (Gatkowska 2017: 66),

for example: moon: night (księżyc: noc),

k. characteristic place (miejsce charakterystyczne), determines the relationship between: people or animals and artifacts or natural objects in which a person or an animal performs characteristic activities, (Gatkowska 2017: 64),

for example: house: family (dom: rodzinny),

3. **causality (przyczynowość),** there is a relationship of cause and effect (Gatkowska 2017: 67),

for example: stomach: hunger (żołądek: głód),

4. **pragmatic dependencies:**

a. name (nazwa), is used of the relationship between animate objects, people, natural phenomena, inanimate objects and their proper names (Gatkowska 2017: 67),

for example: city: Cracow (miasto: Kraków),

b. stereotype (stereotyp) is used of the relationship between persons, animals or artifacts and a widely accepted simplified image, set of judgments or beliefs, (Gatkowska 2017: 68),

for example: lion: king (lew: król),

c. knowledge (wiedza), is used of the relationships between natural objects, phenomena, people, animals, plants and artifacts, which are the result of scientific knowledge, work experience, knowledge of a foreign language (usually an equivalent) or information provided by the media, (Gatkowska 2017: 67),

for example: carpet: Persian (dywan: perski),

5. **composite lexical unit** (złożona jednostka leksykalna), is used of the connection between lexemes, which can be identified as components of a multi-segment lexical unit, such as sayings, proverbs, titles of books, films, etc., sometimes names of people and fictional characters, names, i.e. a very diverse set that has one common property: form a multi-segment lexical unit. (Gatkowska 2017: 68):

for example: sheep: black (owca: czarna), cottage: rich (chata: bogata, in Polish: *czym chata bogata, tym rada*) butter: butter (used attributively) (masło: maślane – pleonasm).

It was possible to identify verbal associations created by the subject as*:*

1. **paradigmatic relations** such as:

a. hyponymy (hiponimia) – fruit: a pear, a pineapple, a banana (owoc: gruszka, ananas, banan), cottage: building, house (chata: budynek, dom), man: human, mister, chap (mężczyzna: chłowiek, pan, facet), priest : clergyman, priest (ksiądz: duchowny, kapłan), vodka: alcohol, beer, vodka, wine, spirits (wódka: alkohol, piwo, wódka, wino, spirystus), butterfly: moth, flying insect (motyl: ćma, owad latający), woman: wife, mother (kobieta: żona, matka), spider: garden spider, tarantula (pająk: krzyżak, tarantula), music: rap, disco, disco polo, girl: madam, woman (dziewczyna: pani, kobieta), soldier: sailor (żołnierz: marynarz), cabbage: white (kapusta: biała) , eagle: bird (orzeł: ptak), eagle: Polish emblem (orzeł: polskie godło), sickness: cancer (choroba: rak), lamp: room lamp, halogen (lampa: pokojowa, halogenowa), doctor: professor (doktor: profesor),chees: cottage, hard chees, moudly chees (ser: bialy, żółty, pleśniowy), bread: wholemeal, ordinary, whith grains, (chleb: razowy, zwykły, z ziarnami),

b. meronymy (meronimia) - foot: leg (stopa: noga), hand: palm (ręka: dloń), street: city (ulica: miasto),

c. synonymy (synonimia) - trouble: problem (kłopot: problem), child: descendant (dziecko: potomek), boy: young man (chłopiec: młody mężczyzna), doctor: physician (doktor: lekarz), baby: baby, little child, descendant (niemowlę: niemowlak, małe dziecko, potomek),

2. **syntagmatic relations**, for example:

a. set (komplet) — table: stool (stół: taboret);
b. location (lokalizacja) — carpet: to the floor (dywan; na podłogę), justice: courts (sprawiedliwość: sądy);
c. taste (smak) — food: good, delicious (jedzenie; pyszne, dobre),
d. intensity (intensywność) – working: heavy, difficult (praca: ciężka, trudna).
e. specific property (właściwość swoista) - cabbage: pickled (kapusta: kiszona)
f. purpose (przeznaczenie) – lamp: luminous (lampa: świecąca),
g. color (kolor) is (the term used for)/used of the relationship between: people, animals, natural objects and artifacts (things) and the properties of their surfaces perceived by eyesight depending on how they reflect or emit light, (Gatkowska, 2017: 62),

   for example: bread: white (chleb: biały)

h. size (rozmiar) - house: big (dom: duży),
i. orientation (orientacja), is (the term used for)/used of the position of an object or its parts in relation to the sides of the human body or the directions of the world (Gatkowska 2017: 66),

   for example: hand: right hand, left hand (ręka: prawa ręka, lewa ręka),

3. **pragmatic dependencies,** for example**:**

   knowledge (wiedza) – window: life window (okno : okno życia)

4. **composite lexical unit** (złożona jednostka leksykalna), occasionally, for example: window on the world, (okno na świat).

The subject used paradigmatic relations, especially hyponymy (18 times), and also more often than the standard gave meanings synonymy (five times), less often meronymy (three times). And among his answers there was no antonymy or complementarity that occurred in the standard.

The subject used syntagmatic relations much less often (10 times) than the standard (20 times), which build the meaning of the lexeme. Additionally, there were no responses that could be identified as causal.

The subject very rarely uses complex lexical units (which, for example, can be sayings, proverbs, complex syntagmatic structures), actually only for the *window* lexeme.

Associations which could not be justified by lexical relations often occurred. Answers of the subject came down to giving definitions of the stimulus words. Sometimes his definition is incorrect, for example: the moon- planet, so we have at night, the moon is shining (księżyc – planeta, tak, że w nocy mamy, księżyc świeci). This verbal behavior significantly deviates from the reactions of healthy people (standard).

For two stimuli (blossom and light), he gave no answer, no reaction.

Psychological Analysis

The researchers conducted qualitative analysis of the data. These methods of analysis gave possibility to develop description of mechanisms and symptoms of speech-language impairments and abilities of the subject.

Types of verbal reactions and their frequency.

Qualitative analysis showed three main categories of verbal reactions of the subject:

- Completely correct verbal reactions

Into this category the researchers included utterances, which were composed of properly semantically connected associative-words, compatible with directions of the researcher, similar to verbal reactions of the heathy group. Completely correct reactions appeared after presentation of 21 from 63 stimuli-words, for example the stimulus-word *table* appeared the association *chair*.

Other verbal reactions (referring to 42 from 63 stimuli-words) can be divided into two main subcategories listed below. They were: atypical reactions and partly correct reactions.

- Atypical reactions

Into this category the researchers included verbal reactions, which were semantically correct and compatible with directions of the researchers. However, this kind of reactions was not observed in the healthy group (exotic names of fruit, personal associations of the subject). The interesting example of this subcategory was the metaphorical association *window on the world,* which appeared after the presentation the stimulus-word *window*. This subcategory contains utterances, which appeared in reaction to 4 out of 63 stimuli-words.

- Partly correct reactions

This category of reactions was divided, because the subject has mostly produced more than one association in response to the particular stimulus-word and some of the responses were correct (*e.g.* stimulus word: woman and lexical associations: wife, mother) and the others are inappropriate (*e.g.* stimulus word: joy and appeared association: happy person). Utterances from this category contain one or more associative words which are inappropriately selected due to semantic connection with stimulus-words (*e.g.* stimulus-word: river and semantically remote association: foreign). 38 reactions of 63 stimuli-words were placed into this category.

The subject experienced significant difficulties in precise and correct realization of directions of the researcher. He also found it difficult to change his incorrect verbal behaviours. He continued creating definitions of stimuli-words even though he had correctly understood and repeated the researcher's instructions. These behaviours can be interpreted as a result of executive disorders.

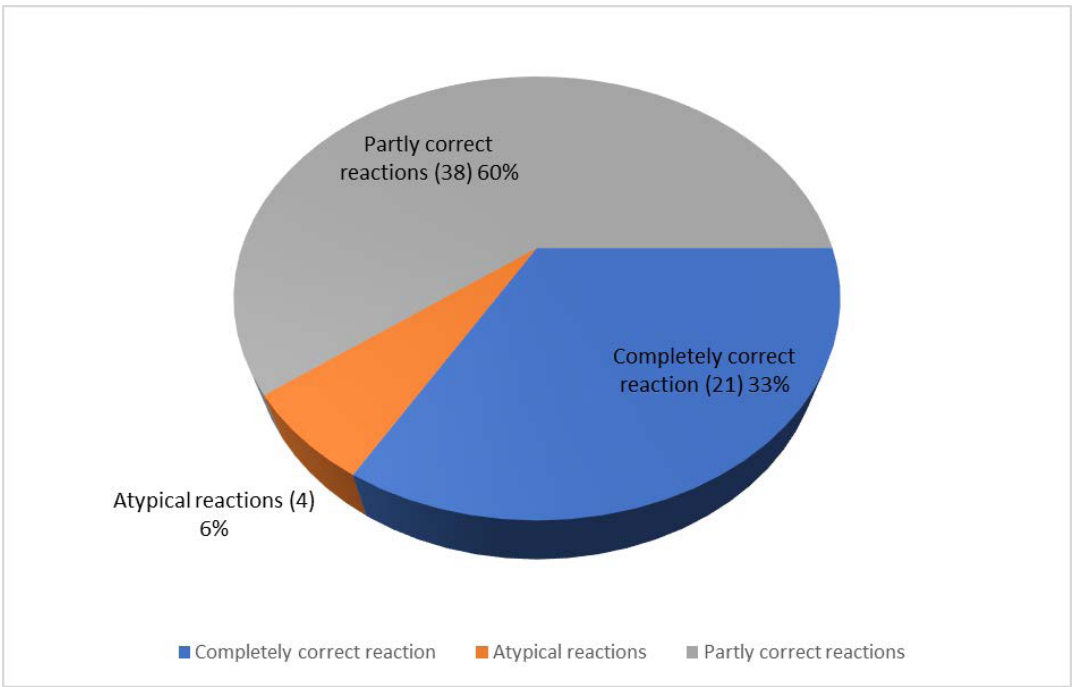

Figure 1. Main categories of verbal reactions and their subcategories. Source: Authors's own work.

The detailed description of reactions which are caused by executive disorders now follows.

- The most common type of imprecise and incorrect verbal reactions of the subject was the attempt to create definitions of stimuli-words' meanings instead of giving lexical associations. Some of the definitions created were correct (*e.g.* stimulus-word: stomach appeared verbal reaction: a part of the human digestive system), while others are inappropriate (*e.g.* stimulus - word: moon prompted the association: planet, so we have: at night, the moon is shining).
- The subject also created his own commentaries to stimuli-words (*e.g.* the stimulus word: health; verbal reaction: may a person be healthy, the stimulus word: memory; the person has a good memory, concentration).

Both of these reactions were inappropriate in the context of the researcher's instructions – instead of verbal associations multi-segment lexical units were produced. Reactions of this kind were observed in 33 cases.

- Repetitions of the stimulus-word (*e.g.*, the stimulus word vodka and the response on it: alcohol, beer, vodka, wine, spirits). These associations were partly correct – the stimulus-word *vodka* and the associated-words: alcohol, wine, beer, spirits are homonyms. The word *vodka* is repeated after two correctly associated words. This type of reaction can be caused by attentive disorders.

The next four types of verbal reactions which were not observed in healthy subjects are listed later in the text.

- Lack of verbal reaction is observed in two cases: after the stimulus-word *light* and after the stimulus-word *blossom*.
- Lack of reaction after the stimulus *light* can be explained as a result of difficulties with processing abstract meanings of words. The conceptualization of the subject was more concrete than in healthy subjects (*e.g.*, house - big, the size 100 square meters - multi-segment lexical unit). The symptoms of concrete thinking were not severe; however, they were visible.
- Lack of reaction to the stimulus-word *kwiecie* (blossom) can be caused by not knowing the meaning of this word, which has a rare form. This verbal behaviour is not connected to cerebellar damage in SCA. The same happened in the control group of healthy adult Poles (standard).
- Repetition of verbal associations (*e.g.*, the stimulus word: the stimulus-word foot and associations lower limb, leg). These kinds of reactions often co-occurred with pauses and slowing down of speech rate. From a linguistic point of view the reaction was semantically correct - the word-stimulus and the associative lexemes are meronyms, but at the same time it was not quite correct from a psychological point of view - two synonymous terms are interpreted as repetitions caused by slowing down of cognitive processes. In all probability, additional pauses and semantic repetitions gave the subject some time to create associations with further stimuli-words. Such a reaction has occurred in two cases.

Discussion of the Results

The authors are aware of the differences between individuals suffering from SCA. Due to this, the results of the conducted study refer primarily to the described subject. In order to obtain results concerning the whole population with SCA, a study conducted on a wider group of patients with this disease is advisable.

Conclusions

The connected psychological and linguistic analysis of the data gave detailed information about the changes in the language functioning of the subject with SCA, as a rare neurodegenerative disease, and have helped to clarify the mechanism of the observed language disorders of the subject.

In conclusion, it can be said that the thesis that cerebellar disorders can be the cause of difficulties in word updating, grammatical competence and semantic disorders has been confirmed, and detailed linguistic and psychological analyses have revealed a precise shape of changes in language functioning.

The language behaviours of the subject turned out to be somewhat reminiscent of the symptoms of aphasia, like grammatical or semantic incompetence. This relates only to a slowing down of the verbal reaction, but this symptom was not observed very often. Some repetitions of the lexemes can be observed. The most common verbal associations of the subject became different than in normal subjects. There were definitions of stimuli or comments on them. These reactions may be interpreted as a result of disorders of control functions. The mental lexicon has partly remained (with the advantage of hyponymy as described in the linguistic analysis). Thanks to this state the subject produced reactions which are semantically

correct. Lack of causality, antonymy and complementarity in paradigmatic relations and difficulties with using syntagmatic relations in produced verbal associations may be interpreted as indicators of disorders in updating words with abstract meaning, which is related to decreased skills in abstract thinking. These linguistic and psychological abilities are crucial in building coherent lexical structure, so we can expect that the subject may present increasing difficulties in creating semantically coherent messages as the disease/disorder progresses.

The incorrect verbal reaction like creating definition and comments to stimuli-words can be interpreted as symptoms of organic disorders, but often they are also closely related to the specific life-situation of the subject (associations related to their state of health).

The results support holistic analysis of human behaviour. The results obtained demonstrate the effectiveness of the chosen method, an interdisciplinary analysis, which has yielded the interesting results we describe. They indicate the reasonableness of combining psychological and linguistic methods and tools in the assessment of speech-language behaviour of people with neurodegenerative diseases as well. Interdisciplinary analysis links characteristics of language utterances and their neurological and psychological determinants. Thus the authors can recommend interdisciplinary observation of speech-language disorders in patients with such diseases, especially the rare ones.

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