Universiteit Utrecht

THE CEREBELLUM'S ROLE IN LANGUAGE PROCESSING AND GRAMMAR ACQUISITION

Deficits in language functioning in the chronic phase after cerebellar stroke and the relationship between implicit learning of grammar and motor control

Keywords: cerebellum, language, implicit learning, grammar, stroke

Abstract

To investigate the role of the cerebellum in language functioning and the relationship between implicit motor learning and implicit grammar learning, an extensive neuropsychological test battery was conducted among 13 patients who were in the chronic phase after cerebellar stroke, and 28 healthy controls who were matched with regard to age, gender and education. The project was divided into two separate studies. The first study aimed to investigate the cerebellum's role in language functioning by comparing patients to healthy controls on a number of language tests (NADL, NWRT, TAK Verteltaak, Verbal Fluency, RAN, EMT, Klepel and six PALPA subtests). A better performance of healthy controls was expected on all tasks in comparison to cerebellar stroke patients. Also, it was expected that patients with left cerebellar damage (*n*=6) would perform better than patients with right cerebellar damage (*n*=5). In the second study, the correlation between an implicit grammar learning task (NADL) and an implicit learning serial reaction time task (ILSRT) was measured in order to investigate the relationship between implicit motor learning and implicit grammar learning. A positive correlation was expected, in which better discrimination ability between grammatical and ungrammatical sentences would correlate significantly with greater differences in reaction time between learnt motor sequences and novel motor sequences. None of the hypotheses were confirmed, although a relationship was found between fine motor skills and phonological memory and processing. Language disorders do not seem to be prominent after cerebellar stroke, which suggests either a good functional outcome after cerebellar stroke due to cerebellar plasticity, or a minor involvement of the cerebellum in language functioning.

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1. Introduction

The cerebellum is a brain structure in the hindbrain that has long been associated with movement control. It is believed to be involved in the regulation of muscle tone, equilibrium, and in the coordination, timing and learning of movement (Rosenbaum, 2010). In particular, research indicates that the cerebellum contributes to *implicit* motor learning. For instance, in 2007, Torriero and colleagues described a case study in which a patient had great difficulty in making automatized movements with his left hand following a left cerebellar ischemic CVA, suggesting a deficit in procedural memory and therefore an involvement of the cerebellum in implicit motor learning (Torriero et al., 2007). These suggestions are supported by other research. Molinari and colleagues showed that unilateral cerebellar lesions severely impaired procedural learning in both hands by using a serial reaction time task, no matter the degree of postlesional motor disturbance. Also, they found that patients with cerebellar lesions had problems with the detection of sequences and the acquisition of declarative knowledge about it (Molinari et al., 1997). Matsumura and colleagues finally argued that the left lateral cerebellum is most prominently activated during the first trial of a novel task ("what to do"), and that the left parasagittal cerebellum may be involved in later learning ("how to do"). Also, they argued that the left cerebellar hemisphere may be involved in asymmetric learning transfer between hands (Matsumura et al., 2004). The cerebellum, therefore, seems to be playing a prominent role in implicit motor learning.

Lately, however, research has put more emphasis on the involvement of the cerebellum in non-motor cognitive functions, in particular affect and language functioning (For extensive reviews, read Murdoch, 2010; de Smet et al., 2007; Highnam & Bleile, 2011; de Smet et al., 2013). Several fields of research – such as neuroimaging, and research among cerebellar stroke patients, patients with the cerebellar cognitive affective syndrome and dyslexics – have found indications that the cerebellum is not only involved in motor functioning, but also in language functioning.

For instance, neuroimaging studies using fMRI and EEG indicate cerebellar involvement in a broad spectrum of linguistic domains, such as phonology, lexical semantics, semantics, syntactic processing and discourse (Kellett et al., 2012). In 2007, Booth and colleagues found in an fMRI study that the cerebellum had reciprocal modulatory effects with phonological processing areas, such as the left lateral temporal cortex and the left inferior frontal gyrus, arguing that the cerebellum is involved in the amplification and refinement of phonological representations (Booth et al., 2007). Also, an EEG study in cerebellar stroke patients showed that there are differences in ERPs between patients and healthy controls when judging ungrammatical sentences, in which patients failed to show an increased syntactic positivity shift in the parietal regions in comparison to healthy controls (Adamaszek, Strecker & Kessler, 2012).

Case studies and experimental research among patients with cerebellar lesions and healthy controls have shown a wide range of deficits in language functioning, like mild agrammatism including morphosyntactic errors in spontaneous speech (Fabbro et al, 2003) and deficits in higher-level language functioning like recreating sentences and formulating definitions (Cook et al, 2004) following cerebellar stroke. Also, Stoodley & Schmahmann (2009) found selective impairments in language functioning in patients with cerebellar degeneration, such as phonemic verbal fluency and word stem completion, arguing an involvement of the cerebellum in searching the lexicon.

Besides previously mentioned selective findings among cerebellar stroke patients and patients with cerebellar degeneration, cerebellar damage sometimes leads to a pattern of clinically relevant behavioural changes sometimes referred to as the 'Cerebellar Cognitive Affective Syndrome' (CCAS). The CCAS is characterized by disturbances of executive functioning (including planning, set-shifting, abstract reasoning, working memory and verbal fluency), spatial cognition (including visuospatial disorganisation and visuospatial memory), personality changes (flattening or blunting of affect and disinhibited or inappropriate behaviour) and linguistic difficulties (including dysprosodia, agrammatism and mild anomia) (Schmahmann & Sherman, 1998; Schmahmann, 2004). The presence of linguistic difficulties following cerebellar lesions in CCAS patients support the indications for cerebellar involvement in language functioning.

Finally, indications for an involvement of the cerebellum in language functioning come from dyslexics. Dyslexia is a learning disorder, which can be divided into two subtypes: *acquired dyslexia*, or dyslexia that occurs after a person has learned how to read (for instance as a result of brain trauma), and *developmental dyslexia*, which is characterized by reading problems that arise during the development of reading skills (Christo, Davis & Brock, 2009). The main characteristics of developmental dyslexia are difficulties in accurate and fluent written word recognition, poor spelling and decoding abilities, language production, language comprehension, and (implicit) language learning (Alphen et al., 2004; Pavlidou, Kelly & Williams, 2010; Snowling & Hayiou-Thomas, 2006). Recent research, however, has uncovered a number of motor impairments among people with developmental dyslexia, such as problems with balancing and implicit motor learning (Howard et al., 2006; Moe-Nilssen et al., 2003; Stoodley, Harrison & Stein, 2006), suggesting an involvement of the cerebellum in dyslexia. Neuroimaging studies support this by showing a reduced grey matter volume in the anterior cerebellum, anomalies in metabolite distribution in the right cerebellum, and diminished connectivity (Brambati et al, 2004; Eckert, 2004, Rae et al, 1998, Finch et al, 2002). Also, Baillieux and colleagues found that dyslexic children display a bilaterally distributed and more diffuse activation pattern while doing a noun-verb association task, thus indicating a deficit in the intra-cerebellar distribution of activity in developmental dyslexics (Baillieux et al., 2009).

Because of the wide variety in language deficits found in patients with cerebellar lesions, and because of the unknown contribution of the cerebellum to the symptoms of dyslexia, the specific nature of the cerebellum's involvement in language functioning remains unclear. Several hypotheses have tried to explain the role of the cerebellum in language processing, among which is the "timing hypothesis", which describes the cerebellum as a modulator of language processing rather than a generator. According to the timing hypothesis, the cerebellum modulates language processing by timing linguistic functions that are represented at the level of the cerebral cortex (Kellett et al., 2012). The cerebello-cerebrocortical diaschisis model supports the view of the cerebellum as a modulator of language, by stating that the cerebellum modulates language functioning via segregated, multi-component neural circuits. Reduced input from the cerebellum to the cerebral cortex via cerebello-cerebrocortical pathways may lead to functional depressions of supratentorial language areas, which causes deficits in language functioning in patients with cerebellar lesions (Murdoch, 2010). However, due to a lack of exploratory research on the topic in a heterogeneous group of participants, little can be said about the validity of these theories.

The present research aims to investigate the role of the cerebellum in language processing by comparing patients with cerebellar lesions to healthy controls. By using an extensive neuropsychological test battery, the results of this research will offer a broad perspective on the cerebellum's contribution to language functioning, in several linguistic domains (e.g. phonology, morphology, semantics, syntax and discourse; production of language and language comprehension; auditory and visual language). Based on previous research and the hypothesis that the cerebellum works as a modulator of language, it is expected that cerebellar patients show more problems on linguistic tasks in general than healthy controls. Also, by including both patients with right cerebellar lesions and patients with left cerebellar lesions, the possibility arises to investigate whether language processing is lateralised within the cerebellum, as it is in the cerebrum. Based on the theory of cerebellar-cerebral diaschisis and the dominant nature of the left cerebral hemisphere in language functioning (Mildner, 2008), we expect to find a significant difference between patients with a left cerebellar lesion and patients with a right cerebellar lesion, in which patients with a right cerebellar lesion perform significantly worse on language tasks than patients with a left cerebellar lesion.

Next to that, the aim of this study is to test the hypothesis that the cerebellum supports implicit learning not only in the motor domain, but also in the language domain. Because of the association of deficits in implicit motor learning and cerebellar abnormalities in dyslexics, combined with impairments in implicit language learning, it is possible that both forms of implicit learning have the same underlying mechanism. Also, the combination of these findings among dyslexics with previously mentioned research among patients with cerebellar lesions, suggests a relationship between implicit motor learning and implicit language learning. By testing both cerebellar stroke patients and healthy controls with an implicit learning serial reaction time task and an implicit grammar learning task, the hypothesis is tested that implicit motor learning is related to implicit grammar learning. Cerebellar stroke patients are expected to perform worse on both tasks than healthy controls, indicating a contribution of the cerebellum in both implicit motor learning and implicit grammar learning. Moreover, a correlation between the performance on both tasks is expected among all participants.

2. Methods

2.1 Participants

A total of 41 people participated in this project, among which were 13 cerebellar stroke patients and 28 healthy controls. All participants were between 30 and 85 years old (M=58.9; SD=13.18) and spoke Dutch as their native language. All patients were right-handed, five healthy controls were left-handed. Exclusion criteria were the presence of psychiatric disorders, attentional disorders (such as ADHD) and dyslexia or any other language related disorders. People could also be excluded after the first test session, in which they were screened for depression (Beck's Depression Inventory; BDI-II-NL; van der Does, 2002), language comprehension impairments (Token test; van Dongen, van Harskamp & Luteijn, 1976), cognitive disorders and dementia (Mini Mental State Examination; MMSE; Kok & Verhey, 2002), neurological abnormalities and ataxia (Brief Ataxia Rating Scale; BARS; Schmahmann et al., 2009) and hearing impairments (audiogram).

There were no significant differences between the two groups with regard to age ($t(39)=.59$; $p=.562$), gender ($Chi^2=0.1$; $df=1$; $p=.756$), or education ($U=180.0$, $p=.951$; a Mann-Whitney U test was conducted due to non-normally distributed data: patients $D(13)=.33$, $p<.05$; controls $D(28)=.29$, $p<.05$) (table 1; figure 1; figure 2). Also, the groups' results on the Token test and MMSE did not differ significantly (Token: $U=125.5$, $p=.200$; a Mann-Whitney U test was conducted due to non-normally distributed data: patients $D(13)=.25$, $p<.05$; controls $D(28)=.20$, $p<.05$) (MMSE: $U=159.0$, $p=.779$; a Mann-Whitney U test was conducted due to non-normally distributed data: patients $D(13)=.27$, $p<.05$; controls $D(28)=.22$, $p<.05$). There was, however, a significant difference between scores on the BDI-II-NL of both groups ($U=85.0$, $p<.05$; a Mann-Whitney U test was conducted due to non-normally distributed data in the control group: patients $D(13)=.19$,

p=.20; controls $D(28)$=.18, p<.05), in which the patient group (M=7.9; SD=1.38) scored significantly higher than the control group (M=3.9; SD=0.80) (Table 2).
All participants provided written informed consent.

Table 1. *Number of participants (N), average age (M) and standard deviations of age (SD) categorized to group and sex.*

	Male			Female			Total		
	N	M	SD	N	M	SD	N	M	SD
Patient	9	64.6	8.50	4	51.9	21.85	13	60.7	14.32
Control	18	57.5	12.67	10	59.2	13.66	27	58.1	12.81
Total	27	59.9	11.80	14	57.1	15.85	41	58.9	13.18

Table 2. *Average scores and standard deviations (SD) per screening task.*

	Token (SD)	MMSE (SD)	BDI-II-NL (SD)
Patients	58.5 (0.54)	29.0 (0.37)	7.9 (1.38)
Controls	57.1 (0.57)	29.0 (0.20)	3.9 (0.80)
Total	57.5 (2.77)	29.0 (1.11)	5.2 (4.79)

2.1.1 Patients

Among 41 participants were 13 patients (9 male, 4 female). All patients were recruited in the university medical centre (UMC) in Utrecht, the Netherlands. Patients either suffered an ischemic or a haemorrhagic cerebellar stroke. One patient also suffered a thalamic infarction, another patient showed extensive white matter lesions on MRI scans. The remaining patients solely had cerebellar lesions. Six patients had left cerebellar lesions, five patients had right cerebellar lesions, and in one patient the vermis was affected. One patient suffered multiple small infarctions in both cerebellar hemispheres (Table 3). On average, the time that had elapsed between the stroke and participation in this project was 4.3 years (SD=1.63), the shortest being 2.4 years. None of the patients received home care at the time of testing.

Table 3. *Types and locations of the cerebellar strokes in the patient group.*

	Location of the lesion				
	Left cerebellum	Right cerebellum	Vermis	Both cerebellar hemispheres	Total
Ischemic CVA	6	4	0	1	11
Haemorrhagic CVA	0	1	1	0	2
Total	6	5	1	1	13

2.1.2 Controls

Twenty-eight healthy controls (18 male, 10 female) participated. Healthy participants were recruited in the local community. People were excluded in case of presence of a neurological disorder.

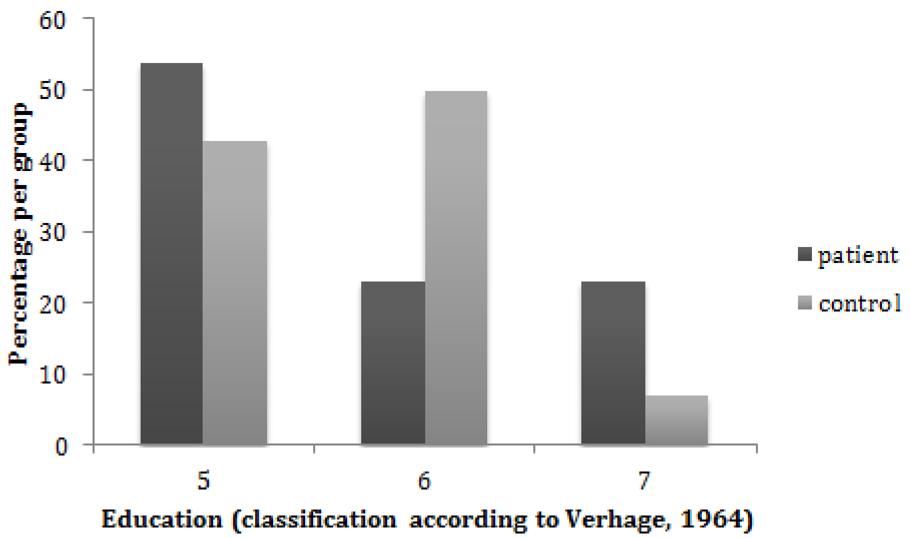

Figure 1. Distribution of education in the patient group and the control group according to the classification system of Verhage (1964), in percentages per group. 5 = MULO/MAVO/MEAO/ MBO; 6 = HAVO/VWO/HEAO/HBS/HBO; 7 = University.

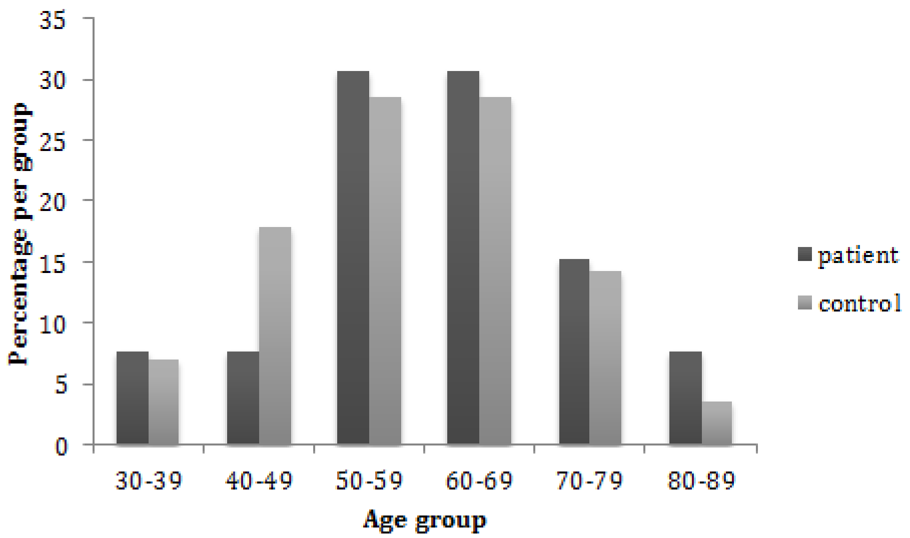

Figure 2. Distribution of age in the patient group and control group, shown in percentages per group.

2.2 Tasks and stimuli

The entire procedure included 28 tasks (21 neuropsychological paper and pencil tasks, 5 neuropsychological computer tasks, 1 neurological assessment and 1 audiogram) and 3 questionnaires. However, not all tasks were used for the final data analysis. A brief overview of all tasks can be found in table 6 and elaborate descriptions of all tasks and stimuli can be found in appendix A. The tasks that were eventually used for data analysis were Nonadjacent Dependency Learning (NADL; Gomez, 2002), Non-word Repetition (NWRT; Dollaghan & Campbell, 1998), Language Test for All Children: Story telling task ("Taaltoets Alle Kinderen: Verteltaak"; TAK Verteltaak; Verhoeven & Vermeer, 2001), Verbal Fluency, Rapid Naming (RAN; Denckla & Rudel, 1974), One-Minute Test ("Eén-Minuut Test"; EMT; Brus & Voeten, 1999), Klepel (van den Bos, 1999), Implicit Learning Serial Reaction time Task (ILSRT; Nissen & Bullemer, 1987), and several subtests of the Psycholinguistic Assessment of Language Processing in Aphasia (PALPA; Kay, Lesser & Coltheart, 2007; Dutch adaptation by Bastiaanse, Bosje & Visch-Brink, 1995).

2.2.1 Nonadjacent Dependency Learning (NADL)

NADL was a computer task which aimed to measure implicit grammar learning. The task consisted of two phases: a learning phase, followed by a testing phase.

In the learning phase, participants were exposed to 378 word strings generated by a miniature artificial grammar. Each string consisted of three pseudowords, in which the first and the last word were always a fixed pair of two one-syllable pseudowords, and in which the second word was always a random two-syllable pseudoword. There were three fixed word pairs: 'rak' + 'toef', 'sot' + 'jik', and 'tep' + 'lut'. Participants had to listen to these strings of pseudowords for about 20 minutes while colouring a mandala. Word strings were presented with a stimulus interval of 1000ms. Numbers were shown on the computer screen, counting down the number of strings. There were no variances in stimuli between participants: all participants were exposed to the same artificial language.

In the testing phase, twelve new strings were presented, in which half of the presented strings were 'grammatical' (i.e. they contained one of the fixed word pairs which were mentioned above), and half of the presented strings were 'ungrammatical'. Participants were asked to identify as quickly as possible whether the presented string was grammatical or ungrammatical, by pressing one of two buttons on a button box. The testing phase started with a training of two sentences, after which the participant had to categorize the twelve sentences.

After completing the task, the researcher asked the participant about explicit knowledge of the task and the language, elements that stood out, and strategies used (appendix F).

2.2.2 Non-word Repetition Task (NWRT)

NWRT was used as a measurement of phonological memory and processing. It consisted of a recording of 48 auditorily presented pseudowords. Each word was presented twice, followed by a pause of 5 seconds. The participant was asked to repeat the words as accurately as possible after the second presentation. Words were incorrect when one or more phonemic errors were made, and correct responses were added up to form a total score. The minimum score was 0, the maximum score was 48. Responses were recorded with a microphone.

2.2.3 TAK Verteltaak

TAK Verteltaak measured the ability to add coherence and meaning to a story. The task consisted of two comics, each consisting of eight pencil drawings. Participants were asked to tell a story based on the presented pictures. Correct elements of the story and correct integrations of these elements were counted to form a final score, with a minimum score of 0 and a maximum score of 32. There were two stories in total, one involving a balloon and one involving a wagon. The order of presentation of these two stories was counterbalanced between participants.

2.2.4 Verbal Fluency

The rate at which participants could produce words from memory was investigated using three different verbal fluency tasks. At first, Categorical Verbal Fluency was used in which participants were given a semantic cue ('animals'), after which they were instructed to generate as many words within that category as possible within one minute. It was not allowed to name several animals within one animal subcategory after mentioning the category as an animal (for example, after saying 'bird', it was not allowed to mention several types of birds anymore). Also morphological variations on one word were not allowed (for example, 'bird' and 'birds').

Secondly, Phonological Verbal Fluency was done, in which participants were asked to name as many words as they could within one minute, starting with a particular letter (phonological cue). Either 'M' or 'K' were used as a first letter. Again, morphological variations on one word were not allowed.

Finally, participants were asked to name as many four-letter-words as they could within one minute starting with the other letter ('M' or 'K'). Which letter was given in which condition depended on counterbalancing.

2.2.5 Rapid Naming (RAN)

Naming speed was measured with RAN, which consisted of six sheets of paper containing different kinds of stimuli. Each sheet had five columns and ten rows, so that every sheet contained 50 stimuli. The first sheet showed a series of numbers, varying from 2 to 11. The second sheet contained a variety of capital letters. The third sheet contained two-dimensional drawings of fish, hats, bicycles, chairs, combs, bread, forks, pears, keys and buckets. Each drawing was shown five times. The fourth sheet consisted of 50 lower case letters. The fifth sheet showed 50 rectangles in different colours; red, blue, green and yellow. The sixth sheet, finally, also showed a series of numbers varying from 2 to 11, except this time the numbers were spread out across the sheet instead of neatly organized in columns. The participant was asked to identify and name what's on the sheets as quickly and accurately as possible, following the direction of the arrow above the sheet. The time it took to complete each sheet was measured with a stopwatch.

2.2.6 EMT & Klepel

EMT was a standardized technical reading test, measuring technical reading skills, which consisted of a list of 116 semantically unrelated words printed in four columns on a single sheet of paper. Participants were given one minute time to read aloud as many words as accurately as possible. Only words read out correctly were scored.

Klepel was a standardized pseudo word reading test, which also consisted of a list of 116 items printed in four columns on a single sheet of paper. By using pseudo words instead of existing words, the ability to transform letters and letter groups into sounds and connect them in order to form words was measured. Participants were given two minutes time to read aloud as many words as accurately as possible. Stress errors were accepted, phonological errors were not.

2.2.7 Psycholinguistic Assessment of Language Processing in Aphasia (PALPA)

The six subtests of the Dutch PALPA that were used were test 6 (auditory lexical decision: morphological endings), 10 (repetition: grammatical class), 11 (repetition: morphological endings), 14 (rhyme judgements: auditory), 49 (semantic word association), and 52 (picture naming and frequency).

2.2.7.1 PALPA 6: Auditory Lexical Decision – Morphological Endings

PALPA 6 consisted of a list of 60 auditorily presented words, of which half (30) were real words and half were fictive. Within these categories, half (15) were words with an inflectional suffix, and half were words with a derivational suffix. Participants were asked to say 'yes' whenever a word was real, or 'no' whenever a word was fictive (table 4).

Table 4. *Number of stimuli in each category of the PALPA 6 task (auditory lexical decision).*

	Existing words	Non-existing words	Total
Inflectional suffix	15	15	30
Derivational suffix	15	15	30
Total	30	30	60

2.2.7.2 PALPA 10: Repetition – Grammatical Class

PALPA 10 consisted of a list of 60 words which was read aloud by the researcher, after which the participant had to repeat the exact same word. Among these words, 15 were nouns, 15 were adjectives, 15 were verbs and 15 were function words. The test was designed to check whether grammatical class influenced the ability to repeat words.

2.2.7.3 PALPA 11: Repetition – Morphological Endings

PALPA 11 consisted of a list of 90 words which was read aloud by the researcher, after which the participant had to repeat the exact same word. Among these words, 15 were words with a regular inflexion, 15 were words with a derivational affix, and 15 were words with an irregular inflexion. The other 45 words were control words which were matched according to their phonological characteristics. This task was designed to check whether problems in repetition were based on morphological or phonological problems.

2.2.7.4 PALPA 14: Rhyme Judgements – Auditory

PALPA 14 consisted of 60 auditorily presented pairs of words. Half of the word pairs rhymed and half of them did not. Among the rhyming word pairs, half of them were orthographically similar (e.g. jas and tas), and half of them were orthographically different (e.g. jam and stem). Among the non-rhyming word pairs, half of them were entirely similar except for the last consonant (e.g. haak and haas), and half of them were entirely similar except for the vowel (e.g. haak and hoek). Participants were asked to judge whether a word pair rhymed or not (table 5).

Table 5. *Number of stimuli in each category of the PALPA 14 task (rhyme judgments: auditory)*

	Rhyming words		Non-rhyming words	
	Orthographically similar	Orthographically different	Different consonant	Different vowel
Nr of stimuli	15	15	15	15

2.2.7.5 PALPA 49: Semantic Word Association

PALPA 49 consisted of a list of 30 visually presented words. Attached to each word were four other words, of which one was a closely semantically related word, one was weakly semantically related, and two were unrelated. The participant was asked to judge which one of the four words was most semantically related to the stimulus word. The first half of the stimulus words were highly imageable, whereas the second half of the stimulus words were low imageable. Participants were instructed not to read the words aloud.

2.2.7.6 PALPA 52: Picture Naming and Frequency

PALPA 52 consisted of a series of 60 pictures (black and white pencil drawings). The participant was asked to describe what he saw on the pictures.

2.2.8 ILSRT

ILSRT was a computer task, consisting of a 'learning phase' and a 'generation phase'. Its aim was to measure implicit sensori-motor learning skills. During the ILSRT, the participant was seated in front of a computer with a button box containing four buttons. After reading the instructions on the computer screen, the participant saw four squares on the screen which corresponded to the buttons on the button box in terms of position. In each trial, one of the four squares lit up, after which the participant had to press the corresponding button on the button box as fast as possible. The coloured square remained visible until the participant pressed one of the four buttons. After a short practice phase, which contained 12 trials, there were seven blocks containing six subblocks of 12 trials. During each block (except for the first and sixth block), the squares on the computer screen lit up in a set order of 12 trials; however this was unknown to the participant. The first and sixth block presented all trials in a random order. In between every two blocks there was a short pause in which a '+' was shown in the centre of the screen for about a second. After the learning phase, the generation phase started, in which the participant was told about the set order and was asked to guess what the order was. The participant had to make three guesses, by sequentially pressing 12 buttons on the button box during every guess. Afterwards, the participant was asked about his or her confidence about the given responses. No feedback was given during both phases.

2.3 Design

Because of the different hypotheses mentioned earlier, the project was divided into two separate experiments, which both complied to one of two main topics.

2.3.1 Study 1: The cerebellum's role in language functioning

First of all, the cerebellum's role in overall language functioning was examined by using NADL, TAK, Verbal Fluency, Rapid Naming, EMT, Klepel, and all PALPA subtests. Results were compared per task between both groups, which lead to a different design per analysis. For NWRT, TAK Verteltaak, EMT, Klepel and Rapid Naming, a non-equivalent groups factorial design was used, including group (patient/control) as independent subject variable and test result (per test) as dependent variable. For the verbal fluency tasks and all PALPA subtests, mixed factorial designs were used, including group as independent between-subjects variable, type of stimuli as independent within-subjects variable and test result as dependent variable.

2.3.2 Study 2: The correlation between implicit grammar and implicit motor learning

In the second part of the study, a mixed 2x7 factorial design was used to investigate implicit learning in the ILSRT task. Here, the between-subjects variable was again 'group' (patient/control) and the within-subjects variables were the different blocks. The dependent variable was the mean reaction time for correct responses. Implicit grammar learning was measured with NADL, by using a non-equivalent groups factorial design, in which the independent subject variable was the group and the dependent variable was d-prime, which indicated the capability to discriminate between grammatically correct and incorrect sentences. Eventually, a correlation was calculated between the d-prime of every participant in the NADL task and the difference in mean reaction time between block 5 and 6 in the ILSRT task.

2.4 Procedure

Participants were recruited through flyers and advertisements and in the local community and by personal approach. People were invited to send an e-mail or give a phone call if they were interested in participation. After receiving a notification of interest from the participant, an information letter was sent to give further information about the study, including the overall aim of the study, a brief description of the tasks, an estimation of the time required for the tasks, and details about payment. When a participant remained interested in participation, a call was made to interview them about several demographic details and details about their mental and physical health, such as age, native language, vision impairments, overall health condition, neuropsychological disorders, reading or learning disorders, medication, and their contact details. Participants suiting all requirements were invited for the first test session.

The procedure consisted of three test sessions of about 1 – 1.5 hours. The first test session was designed to include or exclude participants based on their mental and physical state. In this session, participants were screened for depression, language comprehension impairments, cognitive disorders, neurological abnormalities and hearing impairments. In the other two sessions, participants had to do several neuropsychological tests and computer tasks. All test sessions took place on different days. During the second and the third test session, participants were given the opportunity to have a five-minute break halfway. Participants received €40,- for participation after completing all three test sessions.

Table 6. *All tasks in order of presentation, divided among the three test sessions, including an estimation of the time they take in minutes.*

	Tasks in order of presentation	Estimated time (min)
Session 1	Informed consent	2
	General Information	3
	Dutch Lateralization Inventory	2
	Beck Depression Inventory (BDI-II-NL)	10
	Mini Mental State Examination (MMSE)	10
	Token test	15
	Audiogram	7
	Brief Ataxia Rating Scale (BARS)	10
		Total 59 minutes
Session 2	Implicit Learning Serial Reaction time Task (ILSRT; version A/C)	15
	Non Adjacent Dependency Learning (NADL)	30
	Explicit Learning Serial Reaction time Task (ELSRT; version A/C)	20
	Tone Duration	10
	Stroop	8
	Non Word Repetition Task (NWRT)	12
	Taaltoets Alle Kinderen (TAK): Verteltaak	5
		Total 100 minutes
Session 3	Categorical Verbal Fluency	
	Phonological Verbal Fluency (M/K)	5
	Phonological Verbal Fluency, 4 letters (M/K)	
	PALPA 6: auditory lexical decision: morphological endings	5
	PALPA 10: repetition: grammatical class	5
	PALPA 11: repetition: morphological endings	6
	PALPA 14: rhyme judgments: auditory	5.5
	PALPA 49: semantic word association	8
	PALPA 52: picture naming and frequency	4
	Bourdon-Wiersma Vigilance Task	14
	Rapid Naming	5
	WAIS-III: Similarities	
	WAIS-III: Matrix reasoning	25
	WAIS-III: Digit span forward	
	Eén Minuut Test (EMT)	2
	Klepel	3
	Bead threading	2
		Total 89.5 minutes
Total		248.5 minutes (4:08:30)

3. Results

3.1 Study 1: The cerebellum's role in language functioning

In order to investigate the cerebellum's role in language functioning, a number of language tests were conducted and results were compared between patients and healthy controls, and between patients with left cerebellar lesions and patients with right cerebellar lesions. Table 7 shows the data of NWRT, TAK Verteltaak, EMT and Klepel.

Table 7. *Means (standard deviations) per (sub)group for the Non Word Repetition Task (NWRT), the Language Test for all Children – Story Telling Task (Taaltoets Alle Kinderen- Verteltaak; TAK-V), the One-Minute Test (Eén-Minuut Test; EMT) and the Klepel, including p-values showing levels of significance between patients and healthy controls, and between patients with left cerebellar lesions and patients with right cerebellar lesions.*

Task	Patients			Controls	P-value patients vs. controls	P-value left vs. right hemisphere
	Total	Left hemisphere	Right hemisphere			
NWRT	37.4 (3.15)	38.5 (2.35)	42.8 (1.56)	35.9 (1.60)	0.272	0.180
TAK-V	24.6 (0.92)	24.5 (1.18)	25.0 (1.38)	25.5 (0.74)	0.502	0.787
EMT	92.6 (3.67)	100.5 (3.45)	90.0 (5.12)	95.7 (2.98)	0.547	0.114
Klepel	96.6 (4.36)	106.3 (3.00)	88.0 (8.62)	94.0 (3.14)	0.632	0.058

3.1.1 Non Word Repetition Task (NWRT)

The NWRT aimed to measure phonological memory and processing. The expectation was to find a significant difference between patients and healthy controls, in which healthy controls would perform better than patients. We also expected to find a better performance in patients with left cerebellar damage than among patients with right cerebellar damage. Due to non-normally distributed scores in the patient group ($D(13) = .26$; $p < .05$), a Mann-Whitney U test was conducted to compare patients and healthy controls. Although the average scores of the patients (M=37.4; SD=3.15) were slightly higher than those of the controls (M=35.9; SD=1.60), the difference between the groups was not statistically significant (U=142.5; z=-1.11; p=.272; r=-.17). Also, an independent samples t-test was conducted in order to compare patients with left cerebellar lesions and patients with right cerebellar lesions, which proved to be non-significant as well (t=-1.46; df=9; p=.180).

3.1.2 Language Test for All Children – Story Telling Task ('TAK Verteltaak')

The TAK Verteltaak was used as a measure for discourse, and the ability to add coherence and meaning to a story. We expected to find a better performance among healthy controls than among patients, and to find a better performance among patients with left cerebellar damage than among patients with right cerebellar damage. However, independent samples t-tests showed no significant difference between the patient group and the healthy control group (t=-.68; df=39; p=.502), and neither between patients with left cerebellar lesions and patients with right cerebellar lesions (t=-.28; df=9; p=.787), therefore no difference could be shown in discourse abilities between the groups.

3.1.3 One Minute Test ('Eén-Minuut Test'; EMT)

Technical reading skills were measured using the EMT. We expected to find a better performance among healthy controls than among patients, and to find a better performance among patients with left cerebellar damage than among patients with right cerebellar damage. An independent samples t-test showed no significant difference between patients and healthy controls (*t*=-.61; *df*=39; *p*=.547). Also, no significant difference was found between patients with left cerebellar damage and patients with right cerebellar damage (*t*=1.75; *df*=9; *p*=.114).

3.1.4 Klepel

The ability to transform letters and letter groups into sounds and connect them in order to form words was measured with the Klepel. Again, a better performance among healthy controls than among patients was expected, as well as a better performance among patients with left cerebellar damage than among patients with right cerebellar damage. Independent samples t-tests showed no significant difference between patients and healthy controls (*t*=.48; *df*=39; *p*=.547), however a trend level significance was found between patients with left cerebellar lesions and patients with right cerebellar lesions (*t*=2.17; *df*=9; *p*=.058), in which patients with left cerebellar lesions (M=100.5; SD=3.45) performed slightly better than patients with right cerebellar lesions (M=90.0; SD=5.12).

3.1.5 Rapid Naming and Verbal Fluency

Naming speed was measured using Rapid Naming (RAN). A t-test revealed no significant difference in performance on RAN between patients and controls (*t*=-.16; *df*=39; *p*=.872), indicating no difference in naming speed between the two groups.

Next, the rate at which participants could produce words was investigated using three different verbal fluency tasks. Naming speed as measured by RAN correlated significantly with performance on both categorical verbal fluency (*r*=-.47; *p*<.05) and phonological verbal fluency (τ=-.23; *p*<.05). Also, there appeared to be a trend level significant correlation between naming speed and the phonological verbal fluency condition in which participants were only allowed to name words consisting of four letters (*r*=-.30; *p*=.056). Therefore, and because of the non-significant difference of performance on RAN between patients and healthy controls, naming speed as measured by RAN was added as a covariate to the analysis.

The ANCOVA showed that naming speed was significantly positively related to categorical verbal fluency (*F*(1, 38)=11.36; *p*<.05; *r*=.55). After controlling for the effect of naming speed on categorical verbal fluency, there was no significant difference in performance on categorical verbal fluency between the patient group and the healthy control group (*F*(1, 38)=2.02; *p*=.164; *partial* η^2=.05).

A second ANCOVA revealed a significant positive relationship between naming speed and phonological verbal fluency (*F*(1, 38)=4.81; *p*<.05; *r*=.34). After controlling for the effect of naming speed on phonological verbal fluency, there was no significant difference in performance on phonological verbal fluency between the patient group and the healthy control group (F(1, 38)=1,27; p=.267; *partial* η^2=.03).

Finally, an ANCOVA was conducted to compare results on the phonological verbal fluency task in which only four-letter words were allowed. There was a significant relationship at trend level between naming speed and phonological four-letter verbal fluency (F(1, 38)=3.75; p=.06; r=.30). After controlling for the effect of naming speed on phonological four-letter verbal fluency, there was no significant difference in performance on this task between patients and healthy controls (F(1, 38)=.07; p=.795; *partial* η^2=.00) (table 8; figure 3).

Table 8. *Means (standard deviations) per (sub)group for all conditions of the verbal fluency tasks, including p-values showing levels of significance between patients and healthy controls (after controlling for naming speed), and between patients with left cerebellar lesions and patients with right cerebellar lesions.*

Condition	Patients			Controls	P-value patients vs. controls	P-value left vs. right hemisphere
	Total	Left hemisphere	Right hemisphere			
Categorical (animals)	20.3 (1.90)	22.1 (2.30)	21.8 (3.15)	22.8 (1.15)	0.164	0.926
Phonological (K/M)	13.8 (1.14)	14.8 (1.96)	14.0 (1.52)	15.3 (0.86)	0.267	0.752
Phonological (4 letters)	12.0 (0.92)	14.0 (0.97)	9.4 (1.50)	11.6 (0.87)	0.795	0.026

Interestingly, naming speed did not relate significantly to verbal fluency when both patient subgroups (left cerebellar damage vs. right cerebellar damage) were compared. T-tests were statistically non-significant when comparing patients with left cerebellar damage to patients with right cerebellar damage on both the categorical verbal fluency task (t=.10; df=9; p=.926) and the phonological verbal fluency task (t=.33; df=9; p=.752). However, there was a significant difference between both subgroups on the phonological four-letter verbal fluency task (t=2.66; df=9; p<.05), in which patients with left cerebellar lesions (M=14.0; SD=.97) performed significantly better than patients with right cerebellar lesions (M=9.4; SD=1.5) (table 8; figure 3).

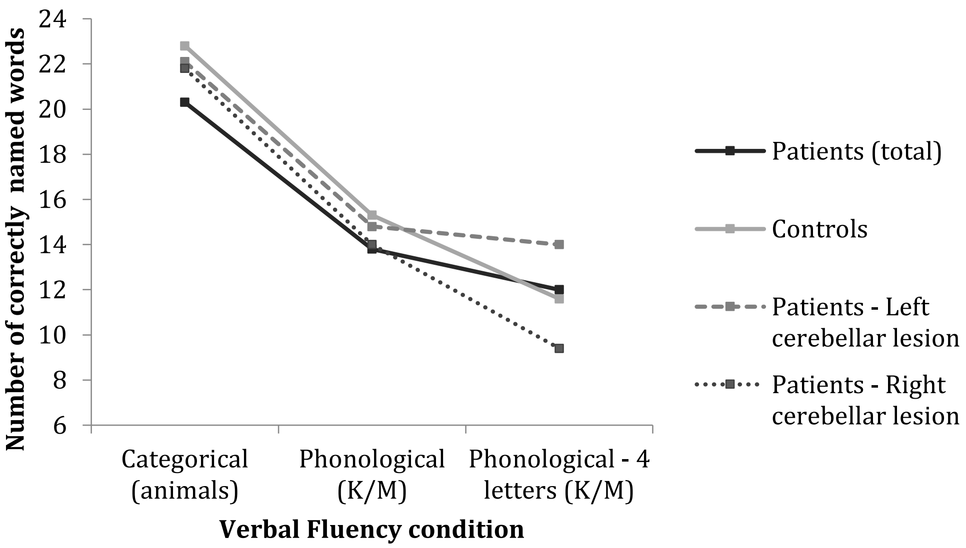

Figure 3. Numbers of correctly named words in every condition of the verbal fluency tasks, shown per (sub)group.

3.1.6 Psycholinguistic Assessment of Language Processing in Aphasia (PALPA)

Six PALPA subtests were used to measure several aspects of language processing. Table 9 shows an overview of all subtests used, including means and standard deviations per (sub)group and significance levels of the differences between groups. Due to non-normal distributions of data in nearly all conditions, Mann-Whitney U tests were conducted in order to compare scores on all subtests between the patient group and the healthy control group. No statistically significant differences were found (PALPA 6: U=126.5, z=-1.57, p=.121, r=-.25; PALPA 10: U=170.0, z=-.43, p=.750, r=-.07; PALPA 11: U=129.5, z=-1.52, p= 0.143, r=-.24; PALPA 14: U=175.5, z=-.19, p=.857, r=-.03; PALPA 49: U=149.5, z=-.94, p=.367, r=-.15; PALPA 52: U=158.5, z=-.67, p=.515, r=-.10).

Table 9. *Means (standard deviations) per (sub)group for all used subtests of the Psycholinguistic Assessment of Language Processing in Aphasia (PALPA), including p-values showing levels of significance between patients and healthy controls, and between patients with left cerebellar lesions and patients with right cerebellar lesions. (PALPA 6 = Auditory lexical decision, morphological endings; PALPA 10 = Repetition, grammatical class; PALPA 11 = Repetition, morphological endings; PALPA 14 = Rhyme judgements, auditive; PALPA 49 = Semantic word association; PALPA 52 = Picture naming and frequency)*

PALPA Subtest	Patients			Controls	P-value patients vs. controls	P-value left vs. right hemisphere
	Total	Left hemisphere	Right hemisphere			
PALPA 6	56.2 (0.49)	56.8 (0.70)	56.0 (0.32)	54.0 (0.81)	0.121	0.341
PALPA 10	59.2 (0.38)	59.3 (0.49)	59.2 (0.80)	59.1 (0.47)	0.750	0.931
PALPA 11	87.5 (0.64)	87.3 (0.99)	88.4 (0.93)	87.6 (0.83)	0.143	0.458
PALPA 14	57.5 (1.18)	59.3 (0.33)	57.4 (1.69)	57.5 (0.80)	0.857	0.249
PALPA 49	28.1 (0.37)	28.0 (0.58)	28.4 (0.51)	28.3 (0.36)	0.367	0.623
PALPA 52	58.5 (0.43)	58.3 (0.56)	59.4 (0.40)	57.6 (0.52)	0,515	0.177

Independent samples t-tests were conducted to compare means between patients with left cerebellar damage and patients with right cerebellar damage, which also proved to be non-significant (PALPA 6: t=1.01, df=9, p=.341; PALPA 11: t=-.78, df=9, p=.458; PALPA 14: t=1.23, df=9, p=.249; PALPA 49: t=-.51, df=9, p=.623). Due to a non-normal distribution of scores on the PALPA 10 subtest in both groups (left cerebellar damage: $D(6)$=.38, p<.05; right cerebellar damage: $D(5)$=.47, p<.05), and a non-normal distribution of scores on the PALPA 52 subtest among patients with right cerebellar damage ($D(5)$=.35, p<.05), Mann-Whitney U tests were conducted for PALPA 10 and PALPA 52. Both tests proved to be non-significant (PALPA 10: U=14.0, z=-.23, p=.931, r=-.07; PALPA 52: U=7.5, z=-1.43, p=.177, r=-.43).

Afterwards, interaction effects were calculated by using repeated measures ANOVAs to see whether patients and controls responded differently to different types of words or stimuli, and to see whether patients with left cerebellar lesions and patients with right cerebellar lesions responded differently to different types of words or stimuli. An overview of all interactions and main effects can be found in table 10. No significant interaction effects were found, however results have to be interpreted with care, due to violations of the assumption of normality. Figures 4-6 show the number of correct answers per PALPA subtest, per type of stimuli and per (sub)group.

3.1.7 Non-adjacent Dependency Learning (NADL)

NADL was used as a measure of implicit grammar learning. D-primes were calculated for the discrimination phase of the task, in which participants had to discriminate between grammatically correct and grammatically incorrect sentences. A higher d-prime among healthy controls than among patients was expected, as well as a higher d-prime among patients with left cerebellar lesions than among patients with right cerebellar lesions. Due to a non-normal distribution of d-primes among the control group ($D(28)$=.24; p<.05), a Mann-Whitney U test was conducted to compare results between patients and healthy controls. This test was non-significant (U=163.5; z=-.53; p=.609; r=-.08), showing no difference in discrimination ability between healthy controls and patients. A Mann-Whitney U test was also conducted to compare patients with left cerebellar damage and patients with right cerebellar damage, due to non-normally distributed scores among the patients with right cerebellar lesions ($D(5)$ = .44; p<.05). This test also proved to be non-significant (U=14.0; z=-.19; p=.853; r=-.06).

However, a brief look at the descriptive statistics revealed a lower d-prime in the control group (M=.05; SD=.13) than in the patient group (M=.21; SD=.25). Also, the average d-prime of left cerebellar patients (M=.14; SD=.38) was lower than the average d-prime of right cerebellar patients (M=.38; SD=.50). A paired-samples t-test of the overall responses (‘yes’ versus ‘no’) revealed a positive response bias among participants ($t(40)$=-3.52; p<.05).

Table 10. *Statistics outcomes of the interactions between group (patients and controls) and type of stimuli/words in the different PALPA subtests, and between location of the lesions (right and left cerebellar lesions) and the type of stimuli, calculated with repeated-measures ANOVAs, including statistics of the main effects, calculated with Mann-Whitney U tests, independent-samples t-tests, Friedman tests and Wilcoxon-Signed Ranks tests. (Type of stimuli: PALPA 6: existing words with an inflectional ending, existing words with a derivational ending, non-existing words with an inflectional ending and non-existing words with a derivational ending; PALPA 10: nouns, verbs, adjectives and function words; PALPA 11: words with a regular inflexion, words with a derivation, and words with an irregular inflexion; PALPA 14: rhyming, orthographically similar word pairs, rhyming, orthographically different word pairs, non-rhyming word pairs in which only the final consonant is different, and non-rhyming word pairs in which only the vowel is different; PALPA 49: high imaginable and low imaginable words; PALPA 52: highly frequent, middle frequent and low frequent words).*

	Patients vs. controls			**Left vs. right cerebellar lesions**		
	Interaction	**Main effect group**	**Main effect stimuli**	**Interaction**	**Main effect group**	**Main effect stimuli**
PALPA 6	F(1.97, 76.64)=1.26; p=.288; *partial* η^2=.03	U=126.5; z=-1.57; p=.121; r=-.25	*Friedman Chi*^{2}=61.45; df=3; p<.05	F(3, 27)=1.54; p=.227; *partial* η^2=.15	t=1.01; df=9; p=.341	*Friedman Chi*^{2}=18.47; df=3; p<.05
PALPA 10	F(1.83, 71.47)=1.34; p=.267; *partial* η^2=.03	U=170.0; z=-.43; p=.750; r=-.07	*Friedman Chi*^{2}=4.95; df=3; p=.175	F(1.48, 13.35)=.32; p=.668; *partial* η^2=.03.	U=14.0; z=-.23; p=.931; r=-.07	*Friedman Chi*^{2}=5.38; df=3; p=.146
PALPA 11	F(2, 78)=.14; p=.871; *partial* η^2=.004	U=129.5; z=-1.52; p= 0.143; r=-.24	*Friedman Chi*^{2}=.60; df=2; p=.741	F(2, 18)=1.54; p=.242; *partial* η^2=.15	t=-.78; df=9; p=.458	*Friedman Chi*^{2}=.42; df=2; p=810
PALPA 14	F(1.58, 61.58)=1.21; p=.297; *partial* η^2=.03	U=175.5; z=-.19; p=.857; r=-.03	*Friedman Chi*^{2}=1.98; df=3; p=.576	F(1.49, 13.41)=1.24; p=.309; *partial* η^2=.12	t=1.23; df=9; p=.249	*Friedman Chi*^{2}=1.47; df=3; p=.690
PALPA 49	F(1, 39)=1.68; p=.203; *partial* η^2=.04	U=149.5; z=-.94; p=.367; r=-.15	Z=-2.92; p<.05	F(1, 9)=1.14; p=.314; *partial* η^2=.11	t=-.51; df=9; p=.623	Z=-2.59; p<.05
PALPA 52	F(1.40, 54.73)=1.40; p=.252; *partial* η^2=.04	U=158.5; z=-.67; p=.515; r=-.10	*Friedman Chi*^{2}=14.66; df=2; p<.05	F(2, 18)=.10; p=.906; *partial* η^2=.01	U=7.5; z=-1.43; p=.177; r=-.43	*Friedman Chi*^{2}=.29; df=2; p=.867

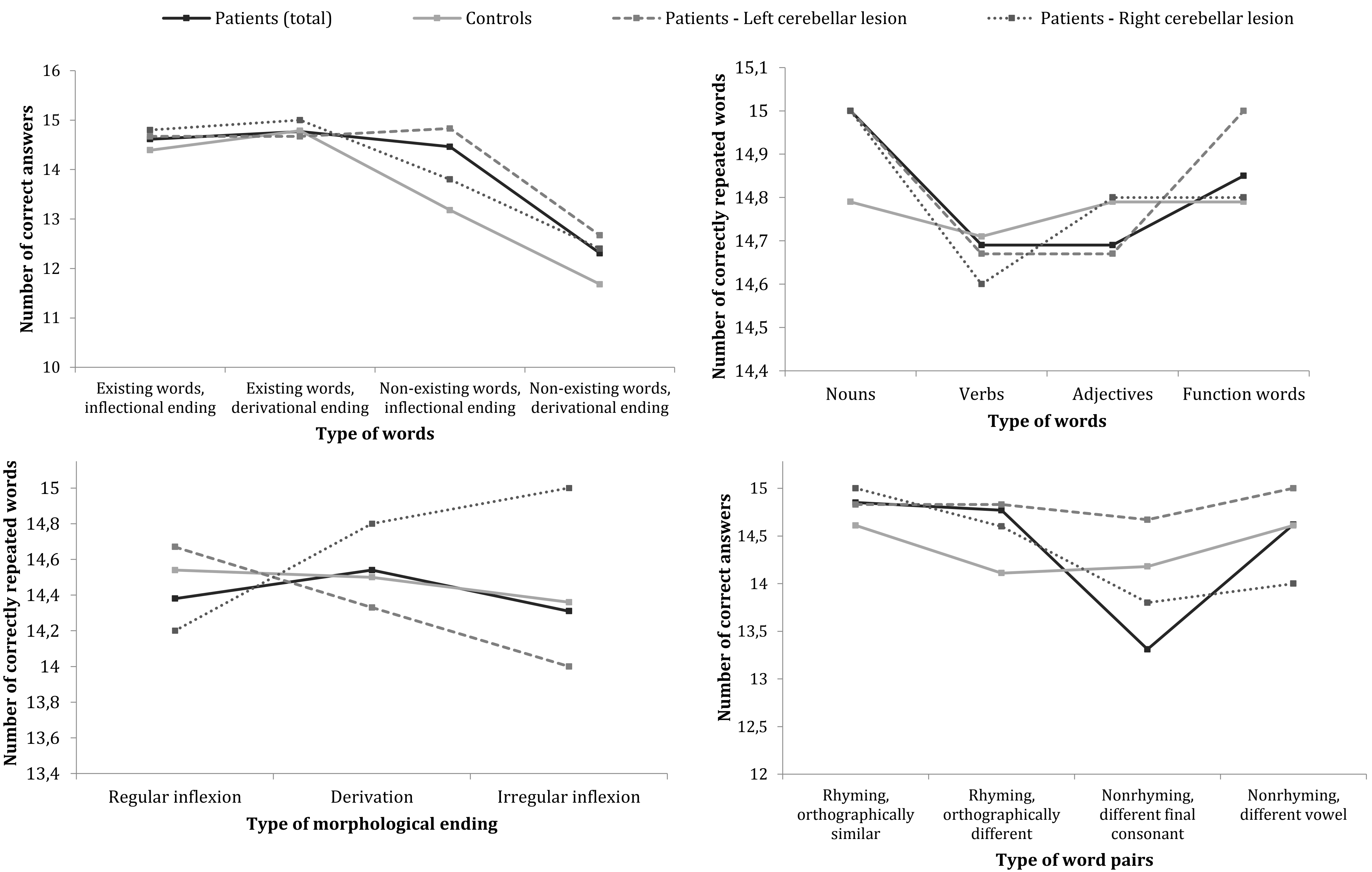

Figure 4. Left top: number of correctly judged words during 'PALPA 6 – Auditory lexical decision, morphological endings' per type of words, shown per (sub)group. Right top: number of correctly repeated words during 'PALPA 10 – Repetition, grammatical class' per type of words, shown per (sub)group. Left bottom: number of correctly repeated words during 'PALPA 11 – Repetition, morphological endings' per type of morphological ending, shown per (sub)group. Right bottom: number of correct answers during 'PALPA 14 – Rhyme judgements, auditory' per type of word pairs, shown per (sub)group.

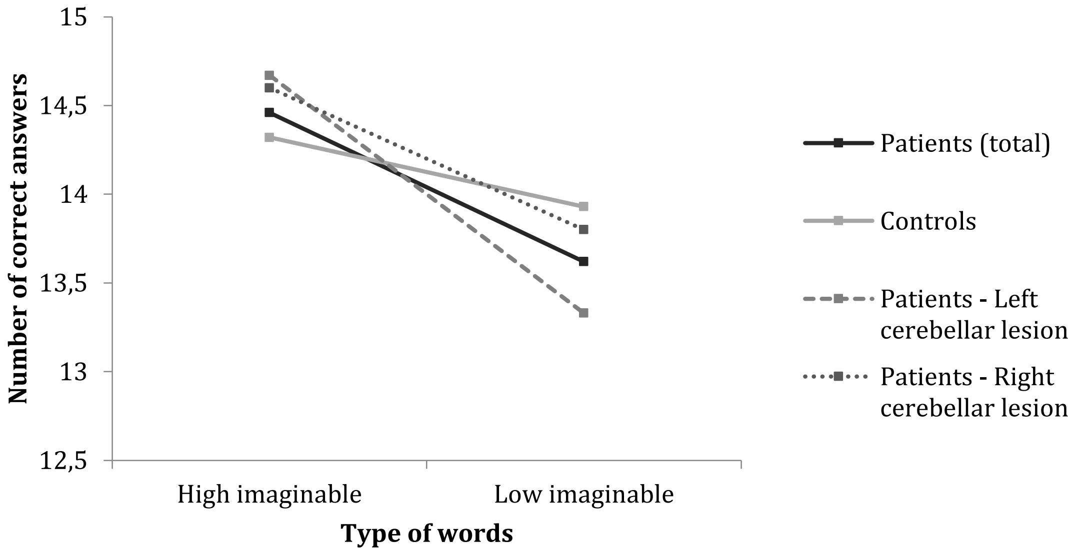

Figure 5. Number of correct answers during 'PALPA 49 – Semantic word association' per type of words, shown per (sub)group.

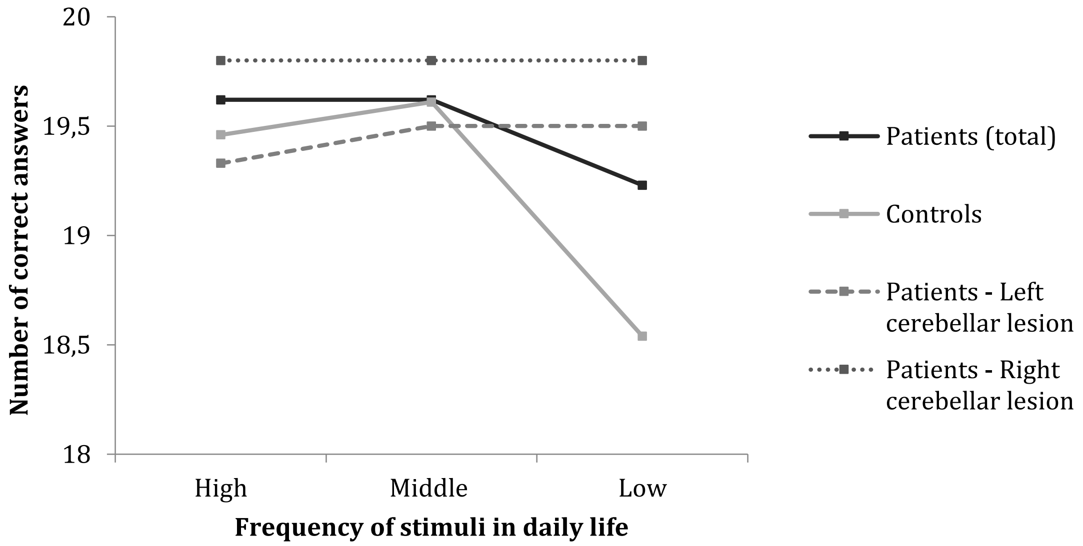

Figure 6. Number of correct answers during 'PALPA 52 – Picture naming and frequency' per frequency level in daily life of the presented stimuli, shown per (sub)group.

3.2 Study 2: The correlation between implicit grammar and implicit motor learning

In the second part of this project, the role of the cerebellum in implicit motor learning and the relationship between implicit motor learning and implicit grammar learning was investigated by looking at the performances on an implicit learning serial reaction time task (ILSRT), and at the correlation between ILSRT and NADL (as described before).

3.2.1 Implicit Learning Serial Reaction Time (ILSRT)

First of all, repeated-measures ANOVAs were conducted in order to investigate learning curves in ILSRT for all (sub)groups. For each participant, the median reaction time of correct responses was calculated per block. Figure 7 shows a decrease in median reaction time for all (sub)groups as the task progresses, including a peak in block 6, in which a new, random sequence was presented. Two repeated measures ANOVAs were conducted, after executing log transformations due to non-normally distributed data and applying Greenhouse-Geisser corrections due to violated assumptions of sphericity. First of all, patients were compared to healthy controls on all ILSRT blocks. The repeated-measures ANOVA revealed a significant main effect for ILSRT block (F(2.67, 103.96)=9.35; p<.05; *partial* η^2=.19), but not for group (F(1, 39)=.90; p=.349; *partial* η^2=.02). Also, there was no significant interaction between group (patients and controls) and ILSRT block (F(2.67, 103.96)=.49; p=.667; *partial* η^2=.12).

Afterwards, patients with left cerebellar damage were compared to patients with right cerebellar damage on all ILSRT blocks. Again, a main effect was found for ILSRT block (F(2.61, 23.48)=5.04; p<.05; *partial* η^2=0.36), but not for group (F(1, 9)=.17; p=.690; *partial* η^2=.02). No significant interaction was found between the location of the lesion (left cerebellar lesions and right cerebellar lesions) and ILSRT block (F(2.61, 23.48)=1.51; p=.239; *partial* η^2=.14).

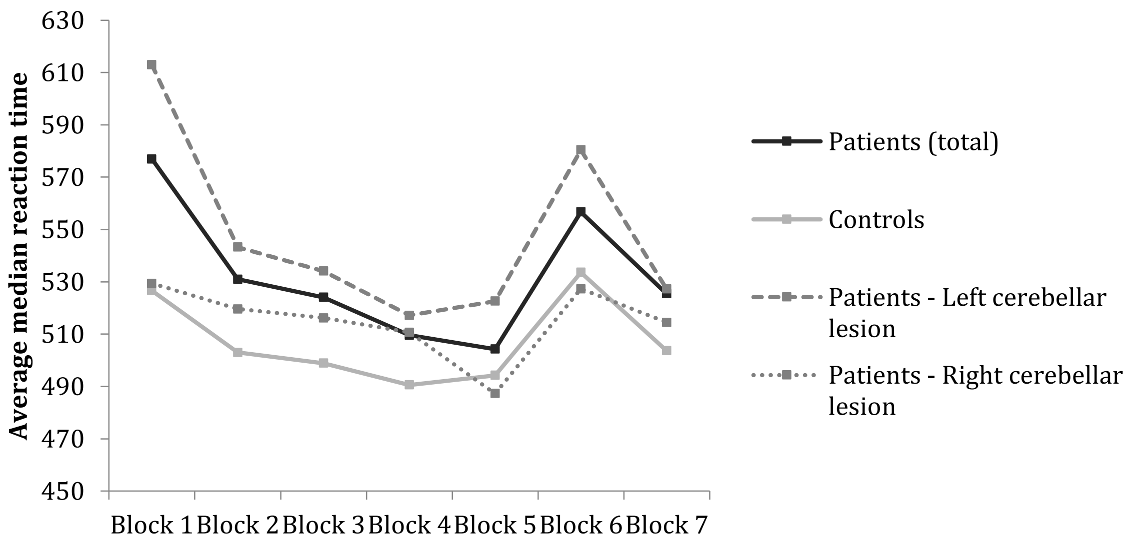

Figure 7. Average median reaction time of correct responses per ILSRT block and per (sub)group.

Next, several blocks were compared to each other by conducting repeated-measures ANOVAs, in order to investigate different parts of the learning process. First of all, block 2 and 5 were compared to look at the difference in learning progress between patients and healthy controls. The learning progress is indicated by the reduction in reaction time as the task progresses. The repeated-measures ANOVA revealed no significant main effect for group (patients and healthy controls; F(1, 39)=.55, p=.464, *partial* η^2=.01) and block (F(1, 39)=3.33; p=.076; *partial* η^2=.08). Also, there was no significant block * group interaction effect (F(1, 39)=.47; p=.497; *partial* η^2=.01), indicating no significant differences in learning progress between the groups.

A second repeated-measures ANOVA compared block 5 and 6. Block 5 and 6 were compared to see how much the knowledge of the learnt sequence interfered with the performance on a random sequence. If participants would have implicitly learned the fixed sequence, it would be expected that the sudden presentation of a random sequence would cause a significant increase in reaction time in the latter block. The repeated-measures ANOVA revealed no significant main effect of group (patients and healthy controls; $F(1, 39)=.50$, $p=.486$, *partial* $\eta^2=.01$). There was, however, a significant main effect of block ($F(1, 39)=34.42$; $p<.05$; *partial* $\eta^2=.47$), in which the average median reaction time was higher in block 6 (M=540.9; SD=19.74) than in block 5 (M=497.4; SD=10.23). Again, no significant block * group interaction effect was found ($F(1, 39)=.51$; $p=.481$; *partial* $\eta^2=.01$), indicating no significant difference in interference of the learnt sequence on a random sequence between the two groups.

A final repeated-measures ANOVA compared block 5 to 7. Block 5 and 7 were compared to see how much knowledge of the learnt sequence was restored. Because both blocks contained the fixed sequence, and because of the presentation of a random sequence in between the two blocks (block 6), block 7 could be used as a measurement of the amount of implicitly stored information when comparing reaction times in this block to reaction times in block 5. No significant main effect of group was found ($F(1, 39)=.49$; $p=.487$; *partial* $\eta^2=.01$). There was a significant main effect of block ($F(1, 39)=9.16$; $p<.05$; *partial* $\eta^2=.19$), in which the average median reaction time in block 7 (M=510.6; SD=17.41) was higher than in block 5 (M=497.4; SD=10.23). No significant block * group interaction effect was found ($F(1,39)=.75$; $p=.393$; *partial* $\eta^2=.02$), indicating no significant difference in the amount of restored knowledge of the learnt sequence between the two groups.

3.2.2 The correlation between ILSRT and NADL

Finally, the absolute difference in median reaction time between block 5 and 6 was calculated per person, which was compared to the d-prime in NADL, in order to investigate the relationship between implicit motor learning and implicit grammar learning. After calculating Kendall's tau, no significant relationship was found between implicit motor learning and implicit grammar learning ($\tau=-.100$; $p=.386$) (figure 8).

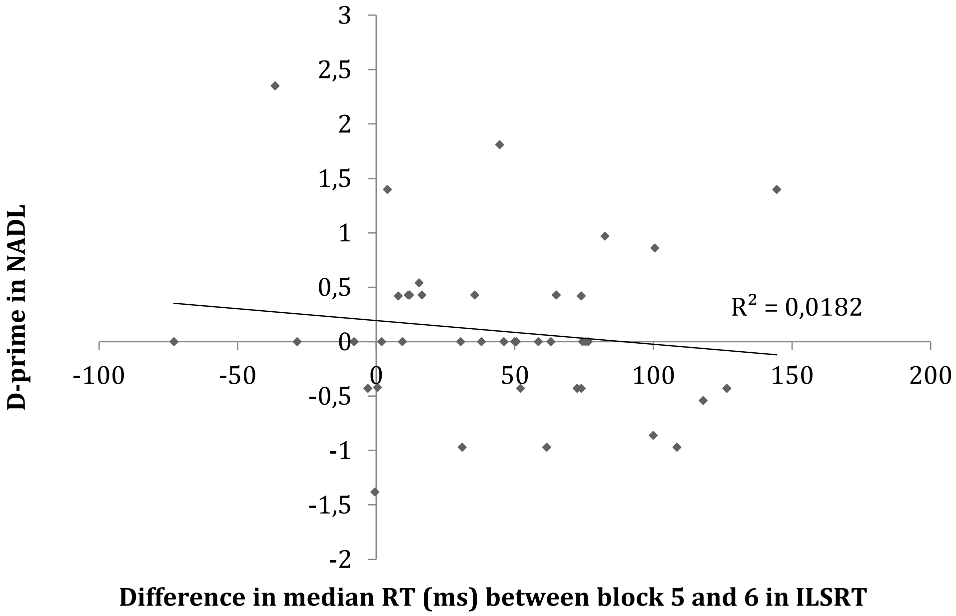

Figure 8. D-prime in NADL, plotted against the difference in median reaction time between block 5 and 6 in ILSRT, presented per participant.

3.3 Correlations with Bead Threading

Because of the great similarities in performances on previously mentioned tasks between patients and healthy controls, the difference in performance on Bead Threading was investigated. Bead threading (see appendix A for further explanation of the task) was used as a measure of fine motor control, and because of the cerebellum's involvement in fine motor control (e.g. grasping; Nowak, Timmann & Hermsdörfer, 2013), it was expected that patients would perform considerably slower on this task than healthy controls. A t-test revealed a significant difference in performance on Bead Threading between patients and healthy controls, in which patients (M=73.2 seconds; SD=12.27) needed more time to complete the task than healthy controls (M=58.5 seconds; SD=10.98), confirming the presence of cerebellar damage. Afterwards, correlations were investigated between performance on Bead Threading and previously mentioned linguistic tasks, which revealed a significant correlation of Bead Threading with performance on NWRT (τ=-.248; p<.05), PALPA 10 (τ =-.343, p<.05) and PALPA 11 (τ=-.386; p<.05). Also, a significant correlation at trend level was found between performance on Bead Threading and EMT (τ=-.208; p=.059) between performance on Bead Threading and TAK Verteltaak (τ=-.194; p=.087) and between performance on Bead Threading and Rapid Naming (r=.275; n=41; p=.082) (figure 9).

Interestingly, no significant correlation was found between performance on Bead Threading and ILSRT (in which the difference in reaction time between block 5 and 6 was used as a measure for implicit learning; r=.051, n=41, p=.749). Also, no significant correlations were found between performance on Bead Threading and other linguistic tasks (NADL: r=.051, n=41, p=,753;

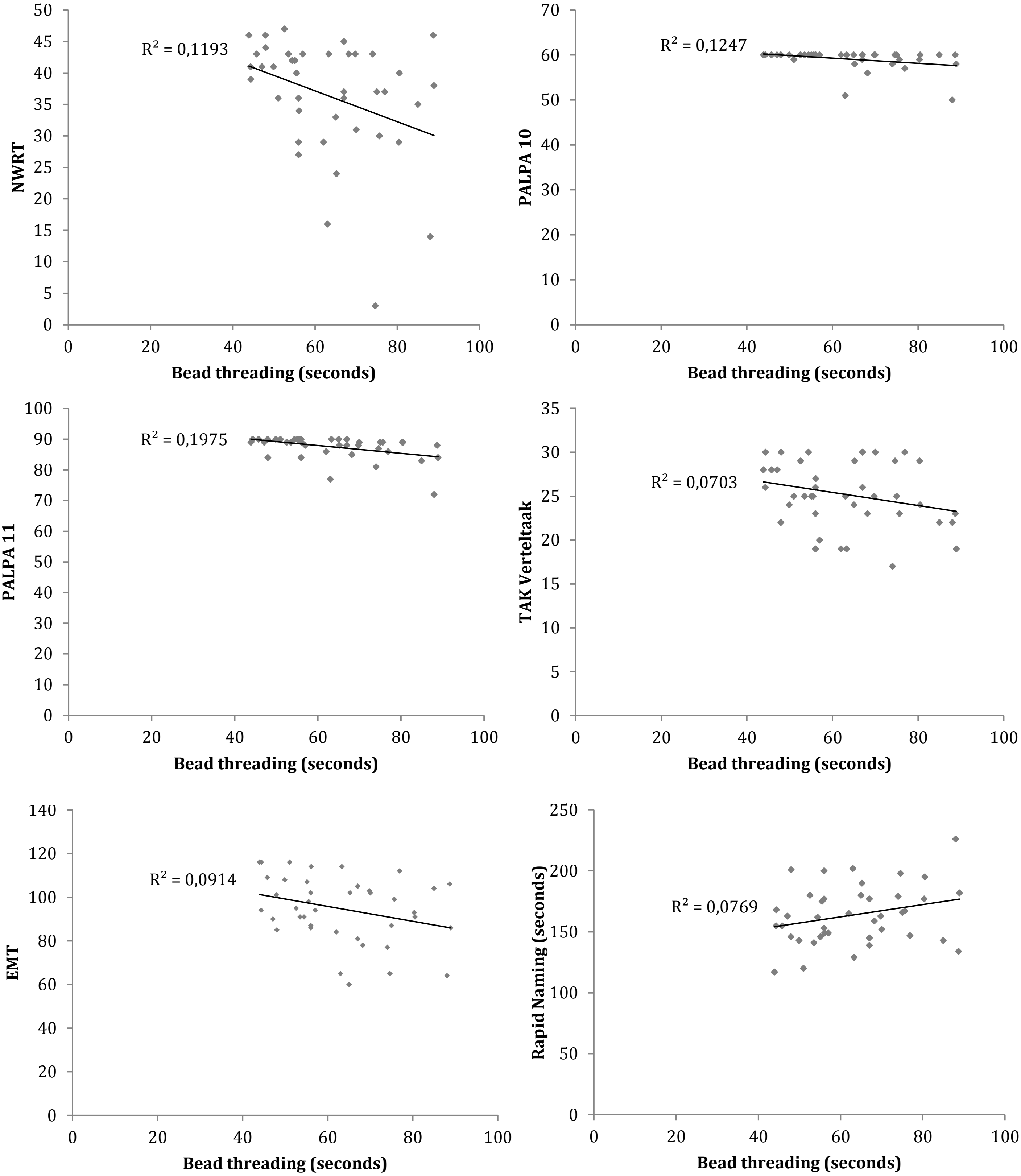

Figure 9. Correlations between performance on Bead Threading (presented in seconds) and number of correct answers on NWRT (left top), PALPA 10 – Repetition, grammatical class (right top), PALPA 11 – Repetition, morphological endings (left middle), TAK Verteltaak (right middle), and EMT (left bottom); and the correlation between performance on Bead Threading (in seconds) and Rapid Naming (in seconds; right bottom).

Categorical Verbal Fluency: τ=-.089, p=.423; Phonological Verbal Fluency: τ=-.091, p=.415; Phonological Verbal Fluency, 4 letters: τ=.028, p=.804; PALPA 6: τ=-1.00, p=.381; PALPA 14: τ=-.137, p=.246; PALPA 49: τ=-.177, p=.134; PALPA 52: τ=-.085, p=.468; Klepel: τ=-.143, p=.192).

4. Discussion

The present project aimed to investigate the role of the cerebellum in language functioning by testing three main hypotheses. First of all, the hypothesis was tested that the cerebellum acts as a modulator of language by controlling cerebral language functioning, which would suggest a decline in overall language functioning after cerebellar damage. Secondly, the hypothesis was tested that language functioning is lateralised within the cerebellum as it is in the cerebrum, in which the right cerebellar hemisphere (according to the theory of cerebellar-cerebral diaschisis) is the dominant linguistic hemisphere. Finally, the hypothesis was tested that the cerebellum contributes to both implicit motor learning and implicit grammar learning, and that there is one mechanism underlying these two forms of implicit learning, which would predict a significant relationship between the two.

In order to test these hypotheses, an extensive neuropsychological test battery was administered to patients in the chronic phase after cerebellar stroke and in a group of healthy controls who were matched with regard to age, gender and education. The statistical outcomes didn't confirm the hypotheses. No differences were found in linguistic functioning between cerebellar stroke patients and healthy controls, and no differences were found between patients with left cerebellar damage and patients with right cerebellar damage. Also, no correlation was found between implicit motor learning and implicit grammar learning.

A couple of results in this project are remarkable, and could therefore lead to an explanation for these findings. First of all, no differences were found in implicit motor learning between patients and controls, which doesn't only reject the hypotheses about the cerebellum being involved in language functioning, but also rejects the hypothesis that the cerebellum is involved in the learning of movements. This contradicts previous findings of Molinari and colleagues (1997), who found a severe impairment of procedural learning on a serial reaction time task after focal cerebellar lesions. An explanation might be found in the exclusion criteria of the present study, which involved the presence of ataxia; a common motor disorder of the cerebellum (Schmahmann, 2004). An absence of ataxia in all patients could indicate a relatively good functional outcome after the stroke, and may therefore explain the absence of deficits in language functioning. A study by Kelly and colleagues (2001) showed that substantial functional recovery after cerebellar stroke is common because of its great plasticity, which suggests that cerebellar damage in the chronic phase after stroke might not be substantial enough when looking at cognitive functioning within the cerebellum. Current lesion sizes should be investigated by using MRI in order to check whether results could be due to cerebellar plasticity.

Another remarkable finding is the absence of grammar learning in both groups on NADL. Results reveal a positive response bias, indicating an inability to detect ungrammaticality in the presented language. This inability can be reproached to the task itself, which proved to be too difficult for both groups. The reason for failure can perhaps be found in the second, distractive task, i.e. colouring the mandala. Research has shown that divided attention declines with normal aging (Verhaeghen & Cerella, 2002), which can account for an absence of attention for the artificial language during the learning phase. Colouring the mandala might have recruited too much attention from the participants, which may have distracted them completely from the actual task.

On the other hand, whereas NADL seemed to be too difficult for most participants, other tasks seemed to be too easy, given the high prevalence of ceiling effects in the data. Ceiling effects lead to a non-normal distribution of data, which makes it hard to detect subtle differences between groups. Thus, the present test battery may not have been sufficiently sensitive to differentiate patients from controls due to small differences in language functioning in cerebellar stroke patients, whereas the present test battery was designed to detect large differences.

However, there are also some conclusions that can be drawn from current project. Even though no significant relationship was found between implicit motor learning and implicit grammar learning, the correlations between fine motor control (as measured with bead threading) and some language tasks do indicate a relationship between motor skills and language functioning. Remarkably, all significant correlations involved tasks in which participants had to repeat an auditory presented word, whether it be existing (PALPA 10 and PALPA 11) or a pseudoword (NWRT). This raises questions about the relationship between fine motor control and the ability to repeat words, or phonological memory and processing. This is in line with previous research on dyslexia, in which dyslexics were found to be considerably slower on Bead Threading than controls (Fawcett & Nicolson, 1995; Ramus, Pidgeon & Frith, 2003). However, research about the exact relationship between fine motor control and phonology is still lacking, and the relationship has not yet been investigated outside dyslexics. The results presented here indicate that this relationship might not be just limited to dyslexics, and suggest a deeper connection between these two functions. Since the patients in the present study were linguistically 'normal' premorbidly, these findings suggest a causal relationship between cerebellar dysfunction and phonological skills. If this is true, future research could focus on replicating current findings, only by using repetition tasks which are more resistant to ceiling effects. Also, tasks measuring phonological awareness without verbal repetition should be added, in order to distinguish phonological skills from buccofacial motor skills. Current project, at this point, is not sufficient to make any statements about what role (if any) the cerebellum plays in the relationship between fine motor control and phonological memory and processing.

Another conclusion that can be drawn from current project is that distinct language disorders are not prominent in the chronic phase after cerebellar stroke. This finding, assuming that the cerebellum does play *a* role in language functioning, suggests a relatively good prognosis in the language domain after cerebellar stroke, which is probably due to cerebellar plasticity. This would be in line with previously mentioned research by Kelly and colleagues (2001) about functional outcome after cerebellar stroke. Deficits in language functioning in the acute phase after cerebellar stroke, however, have not yet been investigated in current or in previous research. Therefore, no firm conclusions can be drawn yet on the course of deficits in language functioning after cerebellar stroke.

Future research could focus on the relationship between fine motor control and phonological memory and processing, and on the underlying mechanism that links the two, for instance by using neuroimaging. Next to that, when looking at language functions in the cerebellum, research might shift its focus onto patients with a more prominent, ongoing cerebellar lesion, for instance patients with a cerebellar tumour or cerebellar surgical dissection. Due to cerebellar plasticity, patients in the chronic phase after cerebellar stroke may not be ideal when investigating cognitive functioning in the cerebellum.

The present study should be replicated in order to confirm the absence of language deficits in cerebellar stroke patients. However, several changes should be made to the test battery. As a replacement for NADL, implicit grammar learning could be tested by distracting participants only partly from the new, artificial language, for instance by letting them watch a video in which people speak the artificial language, while in the meantime visual input is given on a different topic. Furthermore, tests with a better discrimination ability should be used in order to detect subtle language differences between patients and healthy controls.

In summary, current study does not (clearly) indicate abnormalities in language functioning in the chronic phase after cerebellar stroke. The present project does not give indications for a prominent role of the cerebellum in language functioning, and no differences were found between patients with left cerebellar lesions and patients with right cerebellar lesions. No indications were found for a relationship between implicit motor learning and implicit grammar learning. However, current findings suggest a relationship between fine motor skills and phonological memory and processing. Further research should be focussing on replicating these findings, and on investigating the exact nature of this relationship.

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Appendix A: Tasks and stimuli

1. Session 1 (±1 hour)

1.1. Questionnaires (General Information/Dutch Handedness Questionnaire/BDI-II-NL)

The first questionnaire contained 8 open ended questions concerning general (demographic) information, such as date of birth, sex, musicality, medication, and questions about previous participation in research (appendix B).

The Dutch Handedness Questionnaire (van Strien, 2002) and Beck's Depression Inventory (BDI-II-NL; van der Does, 2002) were both self-assessment questionnaires which were filled out by the participants. The Dutch Handedness Questionnaire consisted of 10 items asking about the participant's hand preference in several activities, like brushing teeth and stirring with a spoon. Participants were asked to identify whether they used their left hand, right hand, or alternately in each mentioned activity (appendix C).

The BDI-II-NL consisted of 21 items involving typical characteristics of mood disorders. Every item consisted of a list of 4 statements, which all stood for a different gradation of severity of that specific characteristic, varying from absent to very prominently present. The participant had to tick the answer that most suited his or her mood in the past two weeks including the day of testing (appendix D). Participants with a score higher than 20 out of 63 were excluded.

1.2. Mini Mental State Examination (MMSE; Kok & Verhey, 2002)

The MMSE was a short neuropsychological screening which consisted of a series of short questions and tasks concerning overall cognitive functioning. A total of eleven questions were asked about things like orientation in place and time, memory, motor control, repetition of spoken words, etcetera. Participants with a score lower than 26 were excluded.

1.3. Token test (van Dongen, van Harskamp & Luteijn, 1976)

The Token Test consisted of 20 coloured objects – five big circles, five smaller circles, five big rectangles and five smaller rectangles – in five different colours (blue, white, green, yellow and red). A total of 61 instructions were given by the researcher for specific actions with some of these objects (e.g. *"Take the small blue circle and the large yellow square"* and *"Put the red circle on the green square"*) to check for an accurate comprehension of spoken language.

1.4. Audiogram

The audiogram checked the hearing acuity of the participants by offering several tones at several sound pressure levels (dB), asking the participants to give a sign when hearing a tone. The first tone was presented at 50 decibel, after which the tones decreased with 10 decibel until the participant didn't respond to them anymore, after which the tones increased again with 5 decibel each time until the participant responded to them again. This was done for frequencies of 250Hz, 500Hz, 1000Hz, 2000Hz, 3000Hz, 4000Hz, 6000Hz, and 8000Hz. The left ear and the right ear were tested separately.

1.5. Brief Ataxia Rating Scale (BARS; Schmahmann et al., 2009)

The BARS test was a neurological test which consisted of five relatively simple actions the participant had to perform, like the finger-to-nose test, repeating three sentences to check for dysarthria, and following the researcher's finger with their eyes.

2. Session 2 (±1.5 hour)

2.1. Implicit Learning Serial Reaction Time (ILSRT; Nissen & Bullemer, 1987)

ILSRT was a computer task, consisting of a 'learning phase' and a 'generation phase'. Its aim was to measure implicit sensori-motor learning skills. During the ILSRT, the participant was seated in front of a computer with a button box containing four buttons. After reading the instructions on the computer screen, the participant saw four squares on the screen which corresponded to the buttons on the button box in terms of position. In each trial, one of the four squares lit up, after which the participant had to press the corresponding button on the button box as fast as possible. The coloured square remained visible until the participant pressed one of the four buttons. After a short practice phase, which contained 12 trials, there were seven blocks containing six subblocks of 12 trials. During each block (except for the first and sixth block), the squares on the computer screen lit up in a set order of 12 trials; however this was unknown to the participant. The first and sixth block presented all trials in a random order. In between every two blocks there was a short pause in which a '+' was shown in the centre of the screen for about a second. After the learning phase, the generation phase started, in which the participant was told about the set order and was asked to guess what the order was. The participant had to make three guesses, by sequentially pressing 12 buttons on the button box during every guess. Afterwards, the participant was asked about his or her confidence about the given responses. No feedback was given during both phases.

2.2. Nonadjacent Dependency Learning (NADL; Gomez, 2002)

NADL was a computer task which aimed to measure implicit grammar learning. The task consisted of two phases: a learning phase, followed by a testing phase.

In the learning phase, participants were exposed to 378 word strings generated by a miniature artificial grammar. Each string consisted of three pseudowords, in which the first and the last word were always a fixed pair of two one-syllable pseudowords, and in which the second word was always a random two-syllable pseudoword. There were three fixed word pairs: 'rak' + 'toef', 'sot' + 'jik', and 'tep' + 'lut'. Participants had to listen to these strings of pseudowords for about 20 minutes while colouring a mandala. Word strings were presented with a stimulus interval of 1000ms. Numbers were shown on the computer screen, counting down the number of strings. There were no variances in stimuli between participants: all participants were exposed to the same artificial language.

In the testing phase, twelve new strings were presented, in which half of the presented strings were 'grammatical' (i.e. they contained one of the fixed word pairs which were mentioned above), and half of the presented strings were 'ungrammatical'. Participants were asked to identify as quickly as possible whether the presented string was grammatical or ungrammatical, by pressing one of two buttons on a button box. The testing phase started with a training of two sentences, after which the participant had to categorize the twelve sentences.

After completing the task, the researcher asked the participant about explicit knowledge of the task and the language, elements that stood out, and strategies used (appendix F).

2.3. Explicit Learning Serial Reaction Time (ELSRT; Nissen & Bullemer, 1987)

The ELSRT task was similar to the ILSRT task, only this time the participant had explicit knowledge about the fact that there was going to be a fixed order. The participant was instructed to try to figure out the fixed order during each block, and to try to remember this order. In block 1 and 6, however, there was a random sequence instead of a fixed sequence. This was also told to the participant beforehand. The phases were similar to the ILSRT task, including the 'generation phase', which asked the participant to generate the fixed sequence again by using the button box.

In both the ILSRT and the ELSRT task, there were two conditions which had different sequences. In the first condition, participants were subjected to sequence A in the ILSRT task, and sequence C in the ELSRT task. In the other condition, participants were subjected to sequence C in the ILSRT task, and sequence A in the ELSRT task. The conditions were assigned based on counterbalancing.

2.4. Tone Duration (Gooch et al., 2010)

The Tone Duration task was a time estimation task in which the participant was asked to discriminate between longer and shorter tones. The participant was presented with pairs of tones, after which he was asked to indicate whether the second tone was shorter or longer than the first tone by pressing one of two buttons on a button box. The first tone was always a 1200ms-long pure tone of 392Hz. The second tones varied in duration (400-2000ms), but were otherwise identical. The two stimuli were separated by a one-second silence interval. The task consisted of 66 trials, in which the 22 comparison tones were all presented three times in a randomized order. The task started off with a practice block, in which feedback was given in order to ensure that the participant fully understood the task. No feedback was given during the test block.

2.5. Stroop task (Stroop, 1935)

The Stroop task was again a computer task which aimed to measure selective attention. The computer screen showed a number of words in different colours (blue, yellow and pink), which matched the three colours on the button box. Among these words, there were neutral words and names of colours. Sometimes the colour names were congruent with the colour in which they were presented, but sometimes they weren't (e.g. "BLUE", presented in pink). The participant was asked to press the button on the button box that corresponded to the colour of the letters in which the words were presented, as fast as possible. The task started off with a practice phase in which 8 words were shown. After the practice phase, the testing phase started in which 60 words were presented.

2.6. Nonword Repetition Task (NWRT; Dollaghan & Campbell, 1998)

NWRT was used as a measurement of phonological memory and processing. It consisted of a recording of 48 auditorily presented pseudowords. Each word was presented twice, followed by a pause of 5 seconds. The participant was asked to repeat the words as accurately as possible after the second presentation. Words were incorrect when one or more phonemic errors were made, and correct responses were added up to form a total score. The minimum score was 0, the maximum score was 48. Responses were recorded with a microphone.

2.7. Taaltoets Alle Kinderen: Verteltaak (TAK; Verhoeven & Vermeer, 2001).

TAK Verteltaak measured the ability to add coherence and meaning to a story. The task consisted of two comics, each consisting of eight pencil drawings. Participants were asked to tell a story based on the presented pictures. Correct elements of the story and correct integrations of these elements were counted to form a final score, with a minimum score of 0 and a maximum score of 32. There were two stories in total, one involving a balloon and one involving a wagon. The order of presentation of these two stories was counterbalanced between participants.

3. *Session 3 (±1.5 hour)*

3.1. Verbal Fluency

The rate at which participants could produce words from memory was investigated using three different verbal fluency tasks. At first, Categorical Verbal Fluency was used in which participants were given a semantic cue ('animals'), after which they were instructed to generate as many words within that category as possible within one minute. It was not allowed to name several animals within one animal subcategory after mentioning the category as an animal (for example, after saying 'bird', it was not allowed to mention several types of birds anymore). Also morphological variations on one word were not allowed (for example, 'bird' and 'birds').

Secondly, Phonological Verbal Fluency was done, in which participants were asked to name as many words as they could within one minute, starting with a particular letter (phonological cue). Either 'M' or 'K' were used as a first letter. Again, morphological variations on one word were not allowed.

Finally, participants were asked to name as many four-letter-words as they could within one minute starting with the other letter ('M' or 'K'). Which letter was given in which condition depended on counterbalancing.

3.2. Psycholinguistic Assessment of Language Processing in Aphasia (PALPA; Kay, Lesser & Coltheart, 2007)

The six subtests of the Dutch PALPA that were used were test 6 (auditory lexical decision: morphological endings), 10 (repetition: grammatical class), 11 (repetition: morphological endings), 14 (rhyme judgements: auditory), 49 (semantic word association), and 52 (picture naming and frequency).

3.2.1 PALPA 6: Auditory Lexical Decision – Morphological Endings

PALPA 6 consisted of a list of 60 auditorily presented words, of which half (30) were real words and half were fictive. Within these categories, half (15) were words with an inflectional suffix, and half were words with a derivational suffix. Participants were asked to say 'yes' whenever a word was real, or 'no' whenever a word was fictive (table A.1.).

Table A.1. *Number of stimuli in each category of the PALPA 6 task (auditory lexical decision).*

	Existing words	Non-existing words	Total
Inflectional suffix	15	15	30
Derivational suffix	15	15	30
Total	30	30	60

3.2.2 PALPA 10: Repetition – Grammatical Class

PALPA 10 consisted of a list of 60 words which was read aloud by the researcher, after which the participant had to repeat the exact same word. Among these words, 15 were nouns, 15 were adjectives, 15 were verbs and 15 were function words. The test was designed to check whether grammatical class influenced the ability to repeat words.

3.2.3 PALPA 11: Repetition – Morphological Endings

PALPA 11 consisted of a list of 90 words which was read aloud by the researcher, after which the participant had to repeat the exact same word. Among these words, 15 were words with a regular inflexion, 15 were words with a derivational affix, and 15 were words with an irregular inflexion. The other 45 words were control words which were matched according to their phonological characteristics. This task was designed to check whether problems in repetition were based on morphological or phonological problems.

3.2.4 PALPA 14: Rhyme Judgements – Auditory

PALPA 14 consisted of 60 auditorily presented pairs of words. Half of the word pairs rhymed and half of them did not. Among the rhyming word pairs, half of them were orthographically similar (e.g. jas and tas), and half of them were orthographically different (e.g. jam and stem). Among the non-rhyming word pairs, half of them were entirely similar except for the last consonant (e.g. haak and haas), and half of them were entirely similar except for the vowel (e.g. haak and hoek). Participants were asked to judge whether a word pair rhymed or not (table A.2.).

Table A.2. *Number of stimuli in each category of the PALPA 14 task (rhyme judgments: auditory)*

	Rhyming words		Non-rhyming words	
	Orthographically similar	Orthographically different	Different consonant	Different vowel
Nr of stimuli	15	15	15	15

3.2.5 PALPA 49: Semantic Word Association

PALPA 49 consisted of a list of 30 visually presented words. Attached to each word were four other words, of which one was a closely semantically related word, one was weakly semantically related, and two were unrelated. The participant was asked to judge which one of the four words was most semantically related to the stimulus word. The first half of the stimulus words were highly imageable, whereas the second half of the stimulus words were low imageable. Participants were instructed not to read the words aloud.

3.2.6 PALPA 52: Picture Naming and Frequency

PALPA 52 consisted of a series of 60 pictures (black and white pencil drawings). The participant was asked to describe what he saw on the pictures.

3.3. Bourdon-Wiersma Vigilance Test (Grewelf, 1953)

The Bourdon-Wiersma Vigilance Test aimed to test a participant's visual attention. It tried to measure low-level visual processing, sustained attention and vigilance. The test consisted of an A3 sized sheet of paper with 50 rows, each containing 25 groups of three, four or five dots. The participant was asked to cross out every group of four dots as quickly and accurately as possible. The participant was explicitly told to systematically go along each line, since it was not allowed to make any corrections on the previous lines. The time needed to complete the entire task was measured with a stopwatch.

3.4. Rapid Naming (Denckla & Rudel, 1974)

Naming speed was measured with RAN, which consisted of six sheets of paper containing different kinds of stimuli. Each sheet had five columns and ten rows, so that every sheet contained 50 stimuli. The first sheet showed a series of numbers, varying from 2 to 11. The second sheet contained a variety of capital letters. The third sheet contained two-dimensional drawings of fish, hats, bicycles, chairs, combs, bread, forks, pears, keys and buckets. Each drawing was shown five times. The fourth sheet consisted of 50 lower case letters. The fifth sheet showed 50 rectangles in different colours; red, blue, green and yellow. The sixth sheet, finally, also showed a series of numbers varying from 2 to 11, except this time the numbers were spread out across the sheet instead of neatly organized in columns. The participant was asked to identify and name what's on the sheets as quickly and accurately as possible, following the direction of the arrow above the sheet. The time it took to complete each sheet was measured with a stopwatch.

3.5. Wechsler Adult Intelligence Scale (WAIS-III; Wechsler, 1997)

The three subtests that were used of the WAIS-III are 'Similarities', 'Digit Span Forward', and 'Matrix Reasoning'.

3.5.1 WAIS-III: Similarities

The similarities task consisted of 13 word pairs. Participants were asked to describe the similarities between these words. Correct answers received two points, partially correct answers received one point. Whenever the participant failed to give a two-point answer immediately, additional questions were asked. After four consecutive incorrect answers, the task was discontinued.

3.5.2 WAIS-III: Matrix Reasoning

The matrix reasoning task consisted of 26 matrices, in which one of the pieces is missing. Participants were asked to choose which one was the missing piece out of five possible answers. The task initially started with item 4, however if a participant didn't score the maximum score for both item 4 and item 5, the first three items were also included in the test until the participant had two right answers in a row. Afterwards, the test would be continued with item 6. The test was discontinued after a participant gave four wrong answers within 5 consecutive items.

3.5.3 WAIS-III: Digit Span Forward

The digit span forward task aimed to measure verbal working memory by presenting the participant several sequences of digits, asking the participant to repeat them as accurately as possible after each sequence. The sequences increased in length, starting with two digits and adding one digit after every two sequences. The task ended when a participant failed to repeat two sequences of similar length.

3.6. Eén-Minuut Test (EMT; Brus & Voeten, 1999)

EMT was a standardized technical reading test, measuring technical reading skills, which consisted of a list of 116 semantically unrelated words printed in four columns on a single sheet of paper. Participants were given one minute time to read aloud as many words as accurately as possible. Only words read out correctly were scored.

3.7. Klepel (van den Bos, 1999)

Klepel was a standardized pseudo word reading test, which also consisted of a list of 116 items printed in four columns on a single sheet of paper. By using pseudo words instead of existing words, the ability to transform letters and letter groups into sounds and connect them in order to form words was measured. Participants were given two minutes time to read aloud as many words as accurately as possible. Stress errors were accepted, phonological errors were not.

3.8. Bead Threading (Fawcett & Nicolson, 1995)

The bead threading task was used as a measure of fine motor control, which is associated with cerebellar functioning. The task consisted of a basket containing 15 round wooden beads, with a diameter of 4 centimetres and a hole in the middle with a diameter of 0.5 centimetre, and a string of 85 centimetres long and 3 millimetres thick. These items were placed on a table in front of the participant, the beads inside of the basket and the string outside of the basket. The participant was instructed to take the string from the table and thread the beads to it one by one as fast as possible. It was not allowed to take all beads out of the basket before trying to thread them onto the string; the participant was only allowed to take one bead out of the basket whenever he was finished threading the previous bead.

Appendix B: General Information Questionnaire

Persoonlijke gegevens

1. Voornaam:______________________________
2. Achternaam:____________________________
3. Geslacht m/v
4. Geboortedatum:_________________________

Algemene vragen

5. Bent u muzikaal? Speelt of speelde u een muziekinstrument?_________________________
6. Heeft u als proefpersoon deelgenomen aan ander onderzoek? Zo ja, waaruit bestond dat onderzoek? ____

   ____
7. Hoe hoorde u over dit onderzoek?____
8. Hoeveel uur per week gebruikt u een computer?___________________________________

Appendix C: Dutch Handedness Inventory

Met de onderstaande vragenlijst kunt u bepalen hoe uitgesproken links- of rechtshandig u bent. De lijst bestaat uit één vraag over de hand waarmee u bij voorkeur schrijft en tien vragen met betrekking tot uw voorkeurshand voor andere handelingen. Geef voor elke vraag aan met welke hand u de betreffende handeling gewoonlijk uitvoert.

Schrijfhand
Omcirkel met welke hand u schrijft:

links rechts

Handvoorkeur

Hieronder staat een aantal activiteiten die u met uw linker of rechterhand kunt uitvoeren. Omcirkel welke kant u gewoonlijk gebruikt voor elk van deze activiteiten. Indien u het antwoord niet meteen weet, voer dan de betreffende handeling in gedachten uit. Heeft u geen duidelijke voorkeur, omcirkel in dat geval 'beide'.

1. Met welke hand tekent u?	linker	rechter	beide
2. Welke hand gebruikt u om met een tandenborstel te poetsen?	linker	rechter	beide
3. In welke hand houdt u een flesopener vast?	linker	rechter	beide
4. Met welke hand gooit u een bal ver weg?	linker	rechter	beide
5. In welke hand heeft u een hamer vast als u ermee op een spijker moet slaan?	linker	rechter	beide
6. Met welke hand houdt u een (tennis-)racket vast?	linker	rechter	beide
7. Welke hand gebruikt u om met een mes een touw door te snijden?	linker	rechter	beide
8. Welke hand gebruikt u om met een lepel te roeren?	linker	rechter	beide
9. Welke hand gebruikt u om met een gummetje iets uit te vlakken?	linker	rechter	beide
10. Met welke hand strijkt u een lucifer aan?	linker	rechter	beide

Appendix D: BDI-II-NL

Instructies: Deze vragenlijst bestaat uit 21 rijtjes uitspraken. Lees a.u.b. ieder rijtje aandachtig en kies uit elk rijtje één uitspraak, die het best beschrijft hoe u zich **de afgelopen twee weken met vandaag erbij** gevoeld heeft. Omcirkel het cijfer vóór de door u gekozen uitspraak. Als meerdere uitspraken in een rijtje even goed van toepassing zijn, omcirkel dan het hoogste cijfer van dat rijtje. Let er op dat u niet meer dan één uitspraak per rijtje kiest, ook bij vraag 16 (Veranderingen in Slaappatroon) en 18 (Veranderingen in Eetlust).

1. Somberheid, verdriet

0. Ik voel me niet somber.
1. Ik voel me een groot deel van de tijd somber.
2. Ik ben de hele tijd somber.
3. Ik ben zó somber of ongelukkig dat ik het niet verdragen kan.

2. Pessimisme

0. Ik ben niet ontmoedigd over mijn toekomst.
1. Ik ben meer ontmoedigd over mijn toekomst dan vroeger.
2. Ik verwacht niet dat de dingen goed voor mij zullen uitpakken.
3. Ik heb het gevoel dat mijn toekomst hopeloos is en dat het alleen maar erger zal worden.

3. Mislukkingen

0. Ik voel me geen mislukking.
1. Ik heb te veel dingen laten mislukken.
2. Als ik terugkijk, zie ik een hoop mislukkingen.
3. Ik vind dat ik als persoon een totale mislukking ben.

4. Verlies van plezier

0. Ik beleef net zo veel plezier als altijd aan de dingen die ik leuk vind.
1. Ik geniet niet meer zoveel van dingen als vroeger.
2. Ik beleef heel weinig plezier aan de dingen die ik vroeger leuk vond.
3. Ik beleef geen enkel plezier aan de dingen die ik vroeger leuk vond.

5. Schuldgevoelens

0. Ik voel me niet bijzonder schuldig.
1. Ik voel me schuldig over veel dingen die ik heb gedaan of had moeten doen.
2. Ik voel me meestal erg schuldig.
3. Ik voel me de hele tijd schuldig.

6. Gevoel gestraft te worden

0. Ik heb niet het gevoel dat ik gestraft word.
1. Ik heb het gevoel dat ik misschien gestraft zal worden.
2. Ik verwacht gestraft te worden.
3. Ik heb het gevoel dat ik nu gestraft word.

7. Afkeer van zichzelf

0. Ik voel me over mezelf net als altijd.
1. Ik heb minder zelfvertrouwen.
2. Ik ben teleurgesteld in mezelf.
3. Ik heb een hekel aan mezelf.

8. Zelfkritiek

0. Ik bekritiseer of verwijt mijzelf niet meer dan gewoonlijk.
1. Ik ben meer kritisch op mezelf dan vroeger.
2. Ik bekritiseer mezelf voor al mijn tekortkomingen.
3. Ik verwijt mijzelf al het slechte wat gebeurt.

9. Suïcidale gedachten of wensen

0. Ik heb geen enkele gedachte aan zelfdoding.
1. Ik heb gedachten aan zelfdoding, maar ik zou ze niet ten uitvoer brengen.
2. Ik zou liever een eind aan mijn leven maken.
3. Ik zou een eind aan mijn leven maken als ik de kans kreeg.

10. Huilen

0. Ik huil niet meer dan vroeger.
1. Ik huil meer dan vroeger.
2. Ik huil om elk klein ding.
3. Ik wil graag huilen, maar ik kan het niet.

11. Agitatie, onrust

0. Ik ben niet rustelozer of meer gespannen dan anders.
1. Ik ben rustelozer of meer gespannen dan anders.
2. Ik ben zo rusteloos of opgewonden dat ik moeilijk stil kan zitten.
3. Ik ben zo rusteloos of opgewonden dat ik moet blijven bewegen of iets doen.

12. Verlies van interesse

0. Mijn belangstelling voor andere mensen of activiteiten is niet verminderd.
1. Ik heb nu minder belangstelling voor andere mensen of dingen dan vroeger.
2. ik heb mijn belangstelling voor andere mensen of dingen grotendeels verloren.
3. Het is moeilijk om nog ergens belangstelling voor op te brengen.

13. Besluiteloosheid

0. Ik neem beslissingen ongeveer even makkelijk als altijd.
1. Ik vind het moeilijker om beslissingen te nemen dan gewoonlijk.
2. Ik heb veel meer moeite met het nemen van beslissingen dan vroeger.
3. Ik heb moeite met alle beslissingen.

14. Waardeloosheid

0. Ik heb niet het gevoel dat ik waardeloos ben.
1. Ik zie mezelf niet meer zo waardevol en nuttig als vroeger.
2. Vergeleken met anderen voel ik me meer waardeloos.
3. Ik voel me volstrekt waardeloos.

15. Energieverlies

0. Ik heb nog evenveel energie als altijd.
1. Ik heb minder energie dan vroeger.
2. Ik heb niet voldoende energie om veel te doen.
3. Ik heb niet genoeg energie om wat dan ook te doen.

16. Verandering van slaappatroon

0. Mijn slaappatroon is niet veranderd.
1a. Ik slaap wat meer dan gewoonlijk.
1b. Ik slaap wat minder dan gewoonlijk.
2a. Ik slaap veel meer dan gewoonlijk.
2b. Ik slaap veel minder dan gewoonlijk.
3a. Ik slaap het grootste deel van de dag.
3b. Ik word 1-2 uren te vroeg wakker en kan niet meer inslapen.

17. Prikkelbaarheid

0. Ik ben niet meer prikkelbaar dan anders.
1. Ik ben meer prikkelbaar dan anders.
2. Ik ben veel meer prikkelbaar dan anders.
3. Ik ben de hele tijd prikkelbaar.

18. Verandering van eetlust

0. Mijn eetlust is niet veranderd.
1a. Mijn eetlust is wat kleiner dan gewoonlijk.
1b. Mijn eetlust is wat groter dan gewoonlijk.
2a. Mijn eetlust is veel kleiner dan vroeger.
2b. Mijn eetlust is veel groter dan gewoonlijk.
3a. Ik heb helemaal geen eetlust.
3b. Ik verlang de hele tijd naar eten.

19. Concentratieproblemen

0. Ik kan me net zo goed concentreren als altijd.
1. Ik kan me niet zo goed concentreren als anders.
2. Het is lastig om mijn gedachten ergens lang bij te houden.
3. Ik kan me nergens op concentreren.

20. Moeheid

0. Ik ben niet meer moe of afgemat dan gewoonlijk.
1. Ik word sneller moe of afgemat dan gewoonlijk.
2. Ik word sneller moe of afgemat voor veel dingen die ik vroeger wel deed.
3. Ik ben te moe of afgemat voor de meeste dingen die ik vroeger wel deed.

21. Verlies van interesse in seks

0. Ik heb de laatste tijd geen verandering gemerkt in mijn belangstelling voor seks.
1. Ik heb minder belangstelling voor seks dan vroeger.
2. Ik heb tegenwoordig veel minder belangstelling voor seks.
3. Ik heb alle belangstelling voor seks verloren.

Appendix E: Serial Reaction Time tasks – Answer Sheet

ILSRT

Na 'learning phase':	
Hoe is het gegaan?	
Vond u het moeilijk of makkelijk?	
Hebt u iets bijzonders gemerkt aan de taak?	
(Vertel dat er een vaste volgorde was) Hoeveel van de volgorde denkt u dat u onthouden hebt?	
Na 'test phase':	
Hoe ging het?	
Had u zoiets al eens eerder gedaan (en zo ja, weet u de naam van het experiment nog)?	

ELSRT

Na 'learning phase':	
Hoe is het gegaan?	
Vond u het moeilijk of makkelijk?	
(Vertel dat er een vaste volgorde was) Hoeveel van de volgorde denkt u dat u onthouden hebt?	

Appendix F: Nonadjacent Dependency Learning – Answer Sheet

<table>
<tr><td>Heeft u al eens eerder deelgenomen aan een soortgelijk onderzoek?</td><td colspan="3">Ja</td><td colspan="4">Nee</td></tr>
<tr><td>Hoe zeker bent u van uw antwoorden?</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr>
<tr><td colspan="8">Wat kunt u zich herinneren van de taal? (Wat viel u op?)</td></tr>
<tr><td colspan="8">(In het geval van expliciete kennis) Wanneer/hoe werd u zich hiervan bewust?</td></tr>
<tr><td>Hoeveel woorden had iedere zin?</td><td colspan="2">2</td><td colspan="3">3</td><td colspan="2">4</td></tr>
<tr><td>Wat voor strategie gebruikte u bij uw antwoorden?</td><td colspan="2">Geen</td><td colspan="5">Enige strategie:</td></tr>
<tr><td>Klonk de taal natuurlijk? Was er iets vreemds aan?</td><td colspan="2">Natuurlijk</td><td colspan="3">Vreemd</td><td colspan="2">Wat?</td></tr>
<tr><td>Waren er onderbrekingen in het experiment?</td><td colspan="3">Ja</td><td colspan="4">Nee</td></tr>
</table>

Appendix G: Instructions per task

Session 1:

Informed consent/General information/Dutch lateralization inventory/BDI-II-NL

No instruction needed

MMSE

Ik ga u zo een aantal vragen stellen en opdrachten geven. Wilt u alstublieft uw best doen om zo goed mogelijk antwoord te geven.

Token test

Ik ga u zo korte opdrachten geven met deze fiches. Het is de bedoeling dat u deze direct uitvoert. U moet goed luisteren, want ik mag de opdracht steeds maar één keer geven. Er zijn rechthoeken en cirkels van verschillende kleuren en verschillende grootten. Zou u mij de kleuren van de grote cirkels op willen noemen? (wanneer dit niet lukt, taak afbreken). Dan gaan we nu beginnen.

Audiogram

Ik ga deze koptelefoon over uw oren plaatsen. U zult steeds een toon horen. Dat geluid kan hard of zacht zijn. Als u een toon hoort of denkt dat u een toon hoort, houdt u dan uw hand omhoog. Doe uw hand weer naar beneden wanneer u niet langer de toon hoort. Dus onthoud: houd uw hand omhoog wanneer u een toon hoort en houd uw hand omlaag wanneer u geen toon hoort.

BARS

Zou u voor mij van de ene muur in deze kamer naar de andere muur willen lopen, en weer terug?

…

Zou u hetzelfde rondje willen maken, maar deze keer door te 'koorddansen'? Dus: de hak van de ene voet tegen de tenen van de andere voet, en zo verder.

…

Zou u weer willen gaan zitten, en zou u dan de hak van uw linkervoet op uw rechterknie willen zetten, en zo langzaam met uw linkervoet over uw rechterscheenbeen naar beneden willen glijden? Kunt u dat ook met de andere voet doen?

…

Kunt u uw rechterarm recht voor u uitstrekken, en dan in één beweging uw neus aanraken met uw ogen open? Kunt u dit ook met uw linkerarm doen?

…

Kunt u nu uw ogen sluiten, uw rechterarm recht voor u uitstrekken, en dan in één beweging uw neus aanraken? Kunt u dit ook met uw linkerarm doen?

…

Ik ga nu mijn vinger voor u houden, zou u die in één beweging aan willen raken met uw rechterhand? En nu met uw linkerhand?

…

Zou u de volgende zinnen na willen zeggen:

- "De derde rijdende artilleriebrigade"
- "De kat krabt de krullen van de trap"
- "Slimme Simon smult van de smakelijke soep"

…

Zou u mijn vinger willen volgen met uw ogen, zonder uw hoofd te bewegen?

Session 2:

ILSRT (computer)

Beste deelnemer,

U krijgt straks 4 vierkante vakjes op het scherm te zien. Ieder vakje hoort bij één van de vier knoppen op de knoppenkast. Het vakje in de linkerbovenhoek hoort bij de knop in de linkerbovenhoek, het vakje in de rechterbovenhoek hoort bij de knop in de rechterbovenhoek, enzovoort. De vakjes lichten om de beurt op. Uw taak is om de oplichtende vakjes zo snel en zo goed mogelijk te volgen door de bijbehorende knoppen op de knoppenkast in te drukken. Eerst krijgt u een korte oefening. Daarna begint de echte taak.

Klik op 'ga door' of druk op enter om de oefening te starten.

…

Dat was de oefening. Klik op 'ga door' of druk op enter om door te gaan naar de taak. Veel succes!

…

U zag de vakjes in een steeds terugkerende volgorde oplichten. Deze volgorde bestaat uit 12 oplichtende vakjes. Uw taak is nu om de volgorde te herhalen door op de juiste knoppen op de knoppenkast te drukken. Tijdens het invoeren van de volgorde kunt u onderin het scherm zien hoeveel van de 12 oplichtende vakjes u al ingevoerd heeft. Het is niet mogelijk om te corrigeren. Veel succes!

Klik op 'ga door' of druk op enter om te starten.

NADL

Ik geef u zo een mandala. Uw taak is om deze mandala zo netjes mogelijk in te kleuren. Tijdens het kleuren zult u ongeveer 20 minuten gaan luisteren naar korte zinnen in een 'buitenaardse' taal; deze taal heeft zijn eigen woorden en grammatica en lijkt niet op enige andere taal die u kent. De zinnen bestaan uit drie woorden. U hoeft niet te proberen iets te begrijpen van de buitenaardse taal. Schrijf ook niets op. Concentreer u op het kleuren van de mandala en blijf luisteren. Wanneer het luisterfragment afgelopen is, stopt u dan met kleuren en wacht tot ik u verdere instructies kom geven.

…

U heeft net geluisterd naar zinnen in een buitenaardse taal met bepaalde regelmatigheden. Straks hoort u 12 buitenaardse zinnen die u nog niet eerder heeft gehoord. De helft van deze nieuwe zinnen hoort bij de taal waarnaar u hebt geluisterd en de andere helft hoort er niet bij, maar lijkt er wel erg op. Uw taak is om voor elke zin aan te geven of deze naar uw gevoel bij de taal hoort of niet. Druk op de oranje knop voor 'ja' of op de paarse knop voor 'nee'. Het kan zijn dat u in een zin een woord hoort dat u nog niet eerder hebt gehoord. Ook dan kan de zin horen bij de taal waarnaar u hebt geluisterd. Denk niet na over het antwoord dat u geeft, maar beslis vlot en volg uw intuïtie. Voordat de test begint krijgt u twee voorbeeldzinnen te horen. Veel succes!

ELSRT (computer)

Beste deelnemer,

Deze taak lijkt op een van de voorgaande taken. U krijgt straks weer 4 vierkante vakjes op het scherm te zien, die om de beurt oplichten. Volg de oplichtende vakjes zo snel mogelijk en zo goed mogelijk door op de bijbehorende knoppen op de knoppenkast te drukken. De taak bestaat uit 7 delen. In sommige delen is er een steeds terugkerende volgorde van 12 oplichtende vakjes. In andere blokken lichten de vakjes juist in een willekeurige volgorde op. Probeer voor de blokken met de vaste volgorde te bepalen wat deze volgorde precies is, en probeer deze ook te onthouden.

Klik op 'ga door' of druk op enter om te beginnen. Er is geen oefening. Veel succes!

…

In een aantal delen was er een vaste volgorde van 12 oplichtende vakjes. Uw taak is nu om de volgorde te herhalen door op de juiste knoppen op de knoppenkast te drukken. Tijdens het invoeren van de volgorde kunt u onderin het scherm zien hoeveel van de 12 oplichtende vakjes u al ingevoerd heeft. Het is niet mogelijk te corrigeren. Veel succes!

Klik op 'ga door' of druk op enter om te starten.

Tone duration (computer)

Beste deelnemer,

U zult zo tonen horen via de koptelefoon. De tonen komen in paren. De tweede toon zal korter of langer zijn dan de eerste toon. Uw taak is om voor elk paar zo snel mogelijk aan te geven of u denkt dat de tweede toon korter of langer was dan de eerste. Om te antwoorden, drukt u op de linkerknop op de knoppenkast voor 'korter' en de rechterknop voor 'langer'.

We zullen eerst een korte oefening doen. Druk op één van de knoppen op de knoppenkast wanneer u klaar bent om te beginnen.

…

Einde van het oefengedeelte.

Als u op dit moment nog vragen heeft, stel ze dan nu aan de testleider. Let op: in het volgende deel blijft de taak hetzelfde, maar zult u geen feedback op uw antwoorden krijgen.

Druk op een van de knoppen op de knoppenkast wanneer u klaar bent om verder te gaan. Veel succes!

Stroop (computer)

Beste deelnemer,

In dit experiment zult u woorden te zien krijgen in drie verschillende kleuren: geel, blauw en roze. Het is uw opdracht om op de knop linksboven te drukken wanneer u de kleur blauw ziet, op de knop linksonder wanneer de kleur geel ziet, en op de rechterknop wanneer u de kleur roze ziet. Laat u niet afleiden door de betekenis van de woorden. Eerst zullen we oefenen.

Druk op een willekeurige knop van de knoppenkast om te beginnen.

…

Einde van de oefenronde. Indien u op dit moment vragen heeft, gelieve deze nu aan de onderzoeker te stellen.

Druk op een willekeurige knop van de knoppenkast om verder te gaan.

NWRT

Ik ga u zo een aantal pseudowoorden laten horen, dus niet-bestaande woorden. Deze woorden zullen één voor één uitgesproken worden door de computer. Ieder woord wordt twee keer herhaald, met een korte pauze tussen beide aanbiedingen. Ik wil u vragen om na de tweede aanbieding, het woord zo precies mogelijk te herhalen.

TAK Verteltaak

Ik laat u zo een aantal plaatjes van een stripverhaal zien. U krijgt eerst de tijd om de plaatjes te bekijken, en daarna wil ik u vragen om het verhaal zo duidelijk mogelijk te vertellen. Ik zal uw antwoorden opnemen met de spraakrecorder.

Session 3:

Categorical verbal fluency

Ik ga u zo vragen om zoveel mogelijk woorden op te noemen binnen een bepaalde categorie. Welke categorie dat is, zeg ik zo. Zodra ik de categorie genoemd heb, krijgt u één minuut de tijd om zoveel mogelijk woorden op te noemen die binnen die categorie vallen. U mag alle woorden opnoemen die in u opkomen. Snapt u wat de bedoeling is? Dan gaan we nu beginnen. Noem mij zoveel mogelijk dieren.

Phonological verbal fluency

Nu vraag ik u zoveel mogelijk woorden te noemen die beginnen met een bepaalde letter. Hierbij mag u woorden uit alle categorieën opnoemen, zolang ze maar met die ene letter beginnen. Het is alleen niet de bedoeling dat u een woord herhaalt in een samenstelling of door het te vervoegen. Als u bijvoorbeeld 'tuinman' heeft gezegd, mag u daarna niet meer 'tuin' zeggen. Als u 'tekenen' heeft gezegd, mag u daarna niet meer 'tekent' zeggen. U krijgt hier weer één minuut de tijd voor. Snapt u wat de bedoeling is? Noem mij zoveel mogelijk woorden die beginnen met de letter M/K.

Phonological verbal fluency – 4 letters

Nu ga ik u wederom vragen om zoveel mogelijk woorden te noemen die met een bepaalde letter beginnen. Het enige verschil nu, is dat u alleen woorden op mag noemen die uit 4 letters bestaan. Ook hier krijgt u één minuut de tijd voor. Snapt u wat de bedoeling is? Noem mij zoveel mogelijk woorden met vier letters, die beginnen met de letter K/M.

PALPA 6

Ik zeg zo steeds een woord. Soms bestaat dat woord wél en soms bestaat dat woord níet. Wanneer het woord bestaat, zegt u 'ja'. Wanneer het woord niet bestaat, zegt u 'nee'.

PALPA 10

Ik zeg zo steeds een woord. Wilt u dat woord nazeggen?

PALPA 11

Ik zeg zo weer steeds een woord. Wilt u dat woord nazeggen?

PALPA 14

Ik zeg steeds twee woorden. Wanneer die twee woorden rijmen, zegt u 'ja'. Wanneer die twee woorden niet rijmen, zegt u 'nee'. Ik zal u eerst een aantal voorbeelden geven: Rijmen 'muis' en 'huis'? En 'muis' en 'moes'? En rijmen 'muis' en 'muil'? En 'kuil' en 'muil'? (indien fout, uitleg over rijmen).

PALPA 49

(Bied een presentatieformulier aan.) U ziet steeds een onderstreept woord (wijs het eerste onderstreepte woord aan). U mag dat woord niet hardop zeggen. Achter het woord staan vier andere woorden. Welke van die vier woorden past qua betekenis het beste bij het onderstreepte woord? Voor het woord dat er het beste bij past, mag u een kruisje zetten.

PALPA 52

U ziet zo steeds een afbeelding. Wilt u mij in één woord vertellen wat u afgebeeld ziet staan?

Bourdon-Wiersma Vigilance test

U ziet hier een groot vel met regels die bestaan uit groepjes van 3, 4 of 5 stippen. Het is de bedoeling dat u regel voor regel alle groepjes van 4 stippen zo snel mogelijk doorstreept. Het kan zijn dat u erachter komt dat u een groepje heeft gemist op een vorige regel. In dat geval moet u gewoon doorgaan zonder de fout te verbeteren. Als u er direct achter komt dat u een fout heeft gemaakt, mag u van de streep een kruis maken.

Rapid naming

Ik ga u zo een aantal kaarten laten zien, met daarop steeds een aantal letters, cijfers, kleuren, of afbeeldingen. Bij iedere kaart wil ik u vragen om deze kaart zo goed en zo snel mogelijk helemaal op te lezen, in de richting van de pijl. Let u dus goed op bij iedere kaart in welke richting de pijl wijst.

WAIS-III: Similarities

Bij deze taak lees ik steeds twee woorden voor en u moet zeggen in welk opzicht deze twee woorden aan elkaar gelijk zijn. Bijvoorbeeld: op welke manier zijn een ring en een armband aan elkaar gelijk? [je zou kunnen zeggen dat je ze allebei kunt dragen als versiering, maar 'sieraden' is hier het beste antwoord]. Op welke manier zijn … en … aan elkaar gelijk?

WAIS-III: Matrix reasoning

Zometeen laat ik u een aantal patronen zien. In ieder patroon ontbreekt een stukje. Bekijk het patroon nauwkeurig. Eronder staan telkens 5 losse stukjes afgebeeld. U moet aangeven welk van de losse stukjes in het patroon hoort.

WAIS-III: Digit span forward

Ik ga u nu een aantal cijfers opnoemen. Luister goed, als ik klaar ben moet u die cijfers nazeggen. U moet ze precies zo herhalen zoals ik ze heb gezegd, in dezelfde volgorde. Let goed op, want ik mag de cijfers maar één keer zeggen.

EMT

Ik ga u zo een lijst geven met woorden. Ik zou u willen vragen om deze woorden zo snel maar zo goed mogelijk van boven naar beneden op te lezen wanneer ik 'start' zeg. Wanneer u klaar bent met één rij zonder dat ik u onderbroken heb, mag u meteen verder gaan met de volgende rij, totdat ik 'stop' zeg. U krijgt één minuut de tijd om zo veel mogelijk woorden zo goed mogelijk op te lezen. Begint u maar.

Klepel

U krijgt nu weer een lijst met woorden, net als bij de vorige taak. Het enige verschil is dat u net allemaal Nederlandse woorden hebt gelezen, terwijl u nu een lijst krijgt met woorden die niet bestaan. Ik wil u vragen om deze woorden weer zo goed en zo snel mogelijk op te lezen, op de manier waarop u denkt dat deze uitgesproken zouden moeten worden in het Nederlands. Ook hier geldt weer: als u klaar bent met één rij, mag u meteen verder gaan met de volgende rij, totdat ik 'stop' zeg. U krijgt nu twee minuten de tijd hiervoor. Begint u maar.

Bead threading

U ziet hier een touw en een bak met kralen voor u. Ik wil u vragen om zo, op mijn startsein, het touw op te pakken en de kralen hier zo snel mogelijk één voor één aan te rijgen. Het is de bedoeling dat de kralen die u nog niet aan het touw geregen heeft, in de bak blijven zitten. U mag dus steeds maar één kraal uit de bak pakken om aan het touw te rijgen, en pas wanneer deze eraan zit, mag u een nieuwe kraal uit de bak pakken.