THE EFFECTS OF BRAIN LESIONS ON LANGUAGE:

A COMPARISON OF QUANTITATIVE AND QUALITATIVE RESULTS ON THE BOSTON NAMING TEST FOR PROGRESSIVE AND ACUTE BRAIN LESIONS

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Content

Introduction

In stroke patients, brain lesions are often discovered because the patient shows severe neurological deficits. The lesion can then be located roughly by looking at the patients' deficit: a speech-disorder indicates a lesion in an expressive language center. Generally it is assumed that large lesions lead to multiple and severe deficits. Interestingly though, a patient with a large low grade glioma (LGG) in an expressive language center may not suffer from severe language problems. In fact, in 80% of the patients the glioma is only revealed by the sudden occurrence of seizures (deAngelis, 2002). How can the tumor persist in a latent functional area of the brain while the function is still relatively intact?

This might be due to the nature of gliomas; tumors that arise from the supporting (glial) cells in the brain. They are the most occurring primary brain tumor, with an incidence of 5 to 7 per 100.000[7]. According to the World Health Organisation, the tumors are classified by tumor type and tumor grade. Low grade gliomas are WHO grade I and II. Characteristic for this kind of tumors is that they grow very slowly and infiltrate the surrounding brain tissue. This continuous, constant growth in diameter of the tumor is about 4 mm per year (Mandonet et al., 2003). After this process, the tumor often undergoes anaplastic transformation into the more malignant, higher-grade (III and IV) gliomas.

To make sure this does not happen, LGG-patients often undergo surgery to remove the tumor. This resection cannot be done on the basis of the classical modular view on brain organization, since research has shown that no two brains are the same; the brain is highly personalized. On top of that, because of the infiltrating nature of these tumors, it is more than likely that a portion of the mass will occupy or be contiguous with, functional tissue (Berger et al., 1997). Because imaging methods like fMRI are not exact enough to make sure that none of the remaining functional tissue is removed with the tumor (Duffau, 2005), an awake surgery is performed.

In the awake surgery, a craniotomy is performed and when the brain is exposed, the patient is woken up. The patient is than asked to perform several tasks, associated with different neuropsychological functions. While the patient performs these tasks, the surgeon will induce electric stimulations to specific areas of the brain. When the patient is not able to perform a specific task any more, the surgeon knows that the area that is currently stimulated (and thus not working) is functional tissue. This part of the brain should not be resected for the patient to be able to function properly. The surgeon will do this for the entire area around the tumor, and then only remove the tissue that has not been correlated to any specific function of the brain. Hopefully, the part of the tumor that can be removed is large, so that the patient has a better life-perspective.

Anomia

While the gliomas are most often discovered by the occurrence of seizures and not by other clinical phenomena, this does not mean that they are not there. Depending on the location of the tumor, the clinical phenomena that occur are loss of strength, sense, language or sight, physical changes and cognitive disorders (Klein, 2004). The focus here will lay on language, since 37-58% of the patients with a left-sided intracranial tumor has some degree of language dysfunction (Whittle et al., 1998). When the tumor is located in an expressive language center, the patient might (among other problems) suffer from naming problems (anomia): he or she is not able to name objects of which he or she does know what it represents.

Anomia can be assessed with the Boston Naming Test (BNT, Kaplan et al., 1983). This is a picture-naming test consisting of 60 items that decrease in frequency (Kaplan et al., 1983). So the first item is 'bed', a high-frequent word, which is probably easy to name. The last item is 'abacus', a very infrequent word, which is probably very difficult to name. A patient with anomia has problems with the naming of different objects and/or concepts. He might know exactly what is meant, but is not able to produce the actual word.

The BNT is a highly sensitive tool to assess quantitative as well as qualitative anomia in different groups (Heesbeen et al., 2001). Quantitative results are used frequently, especially with aphasic patients. It is easy to categorize aphasic patients in terms of how many errors the patient makes. But it can also be interesting to look at qualitative results, since different anomic groups might make different errors.

Qualitative errors on the BNT

There are various kinds of errors a patient can make while naming objects; roughly, they can be divided in semantic, phonemic and unrelated errors.

Semantic errors arise when there is an impairment in the mental lexicon. When the picture is recognized, the patient has to find a concept in his semantic memory (the mental lexicon) which represents this picture well. There is still some discussion about how this lexicon is represented in the brain. I will shortly discuss two models: a 'hierarchical' model and a 'spreading activation' model.

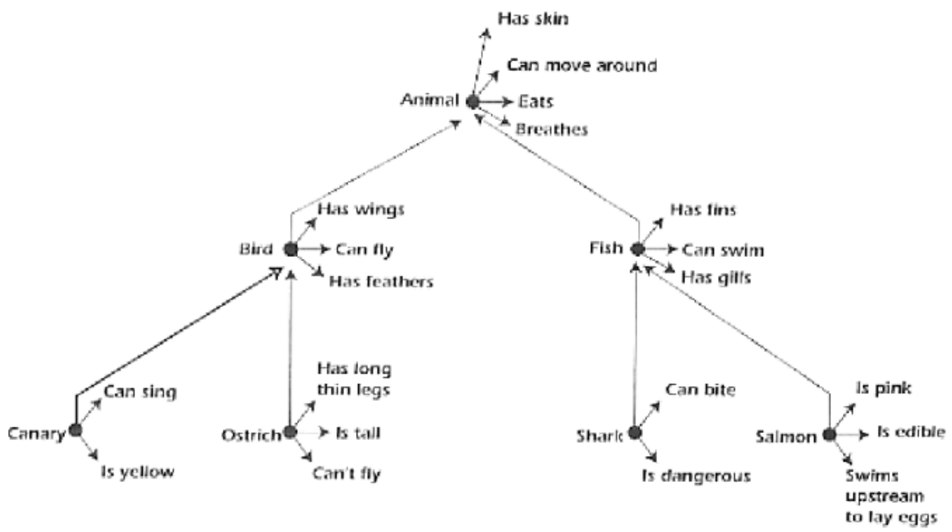

Figure 1: the Hierarchical model of Collins and Quillian (1969)

In the hierarchical model (Collins and Quillian (1969)) the concepts are related in a hierarchical network, as seen in figure 1. Concepts are represented as nodes, and each of the subordinate nodes inherits the properties or features (indicated here by arrows) from the nodes above. Thus, there are some basic properties that any animal will have (like 'eats' and 'breaths'). The hierarchy can be divided in three levels: the superordinate level (animal in this example), the basic level (bird, fish) and the subordinate level (canary, shark). The basic level is said to be cognitively most important, as it is also learned first by children. When the mental lexicon is (partially) impaired, on basis of this model, we expect that this basic level is best preserved. Therefore, when a patient sees a picture of a canary, he is expected to name a superordinate concept (on the basic level) instead, for example 'bird'.

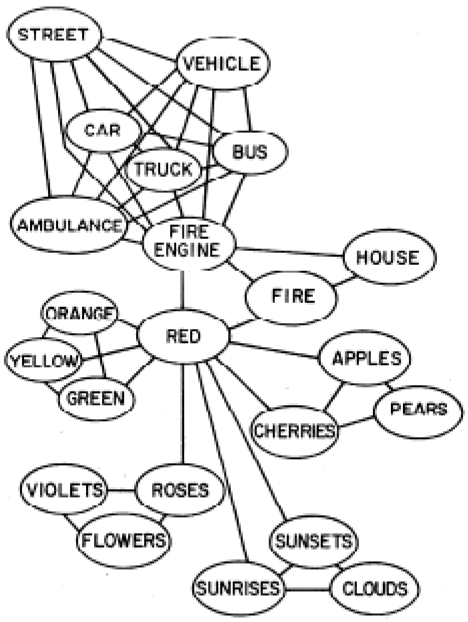

Figure 2: The spreading activation model of Collins and Loftus (1975)

The second theory that I would like to discuss is a spreading activation model (Collins and Loftus, 1975). This model also assumes that the different concepts are connected, but this relationship is not hierarchical (figure 2). When concept is activated, the activation spreads; giving much activation to closely related concepts and less activation to concepts that are less related. For example, when a person sees a picture of fire, 'fire engine', 'house' and 'red' are also very active in this example. On the other hand, 'street' will not be very active since it is not closely related to 'fire'. In this model, when a patient has an impairment in the mental lexicon, it is likely that he will use semantic paraphasias; he will name concepts that are semantically related to the intended concept, since they are also very active (for example: the patient will say 'brown' when a pretzel is meant).

Other semantic errors, not directly explained by the models above, are descriptions and semantic neologisms. When a patient does know the concept, but does not know how to say it (tip of the tongue-phenomenon) he or she may use a description to solve this problem. A semantic neologism is more or less the same thing: the patients might use a non-existing word like 'walking-sticks' for 'stilts'.

In the case of phonemic errors, patients often know the name but have problems with the selection of the corresponding phonemes. An example: the patient tries to say 'stethoscoop' but instead says 'telescope'. Here, it is clear the patient knows what the concept represents, but he is not able to produce the correct word (formal phonemic paraphasia). It could also be that the patient makes so many mistakes in the selection of the phonemes of a word that this leads to a new, non-existent word (phonemic neologism).

Further types of errors, where it is unclear if the patient knows what the picture is meant to represent might be 'don't know'-answers, visual misperceptions ('snake' for pretzel), meaningless language ('brabala' for 'bed') and totally unrelated answers ('judging' when 'bed' is meant).

Differences between LGG- and CVA-patients

Not all anomic patients will make all the errors described above. It is hypothesized that different causes of anomia induce qualitatively different naming problems. As said above, anomia may be caused by LGG's, but this is not the only lesion that can induce naming problems. Naming problems can also arise in patients who have had a cerebral vascular accident (CVA). There are differences between naming problems in progressive lesions like low grade gliomas and acute lesions like CVA's. One of the differences is that CVA-patients make a lot more errors on the Boston Naming Test than LGG-patients do. Another difference is that LGG-patients show very mild or no neuropsychological deficits, while more than 70% of the stroke-patients still suffer from mild to severe deficits after 11 years (Varona et al., 2004).

We thus see that stroke victims not only have more severe language problems, but that they are also much less likely to improve over time. LGG patients, on the other hand, rarely suffer from severe language problems at all.

These differences have to do with brain plasticity: the capacity of the brain to reorganize itself. This functional reorganization is seen during natural brain-development, but also post-lesional. Plasticity enables the brain to compensate for the lesioned area by recruiting another area to perform this function. An interesting hypothesis about how this functional redistribution works is posed by Desmurget et al (2007):

" *A gradual learning process mediates brain plasticity. According to this idea, plastic adaptations take place through supervised learning. Eloquent areas would then play the role of a 'distant teacher' (Jordan and Rumelhart, 1992). This teacher would instruct intact regions through direct or indirect pathways, providing these regions with new functional competences* [1]."

If the hypothesis of Desmurget et al (2007) is correct, the main factor accounting for the differences between LGG-patients and CVA-patients is time. A low grade glioma is a slow, progressive lesion which has probably been in the brain for years before it is discovered trough the sudden occurrence of seizures. Since the tumor grows so slow, the brain has had enough time to reorganize properly. That is why LGG-patients show no severe neurological deficits: the function is compensated before the tumor becomes too large.

CVA's, on the other hand, are acute. The lesion is there at once, at full size. There is no time for a gradual reorganization of the brain; the reorganization is fast and less efficient. That is why the deficits will be more severe and will probably manifest itself differently.

The hypothesis that is tested in this research is then: when the lesion is slow-growing as in the case of low grade gliomas, the reorganization is gradual and there is more time for the latent functional areas to adapt to the lesion, thus leading to less and perhaps different errors than patients with acute lesions, where the reorganization has to be fast and is less efficient.

This assumption can be tested by using results on the Boston Naming Test from LGG- and CVA-patients. As said before, the BNT can be used to assess both quantitative as qualitative anomia.

[1] (Desmurget, Bonnetblanc en Duffau, Contrastic acute and slow-growing lesions: a new door to brain plasticity. Brain 2007; 130: 898-914*)*

The use of quantitative results on the BNT

Pre- and post operative LGG-patients

Quantitative results can be used to test whether the brain of LGG-patients has indeed been reorganizing for years before the tumor is discovered. When the tumor is discovered, patients often undergo awake surgery to remove it (see above). To assess whether a brain-function is not working during the surgery, the surgical team must know how the brain functioned before the surgery. For the language function, the Boston Naming Test is part of the neuropsychological assessment. The same tests are also done three months after the surgery, to see if there is any improvement in the different neurological functions, one of which is the language function.

By comparing the quantitative results on the pre-operative BNT with the results on the test three months after the surgery it can be tested whether the brain has been reorganizing for years, or that it only starts to reorganize after the tumor is removed. When the reorganization has been going on for years, there should not be significantly more errors on the BNT after the surgery than before the surgery, since the (removed) lesioned area is properly compensated for.

This sort of comparison is done before, for instance by Whittle et al. (1998). They have found that the BNT scores in anomic patients did not decrease after the surgery, but they did show a significant increase: the patients made less errors after surgery. This is not what is predicted above: when the lesioned area is properly compensated for, there would not be a significant difference in the amount of errors before and after surgery. The results can be explained by something Duffau (2005) said: the function of the impaired area moves to another part of the brain, but only if it cannot exist inside the original area any more. It might be the case that the language function still persisted in the original area and that the reorganization has not (completely) taken place.

This assumption is supported by the fact that most of the patients in the research of Whittle et al. did have severe naming problems: 24 of the 38 patients were classified anomic (score < 48) preoperatively. When the tumor is removed (using electrical stimulations to make sure that no functional tissue was removed with it), the area was not affected anymore and the language function could be restructured to its old state.

In this research, this sort of results are not expected, since the LGG-patients have no severe naming problems. This indicates that there has been reorganization in the brain and thus that there will be no significant differences in the amount of mistakes patients make before and after surgery.

LGG-patients versus CVA-patients

Quantitative results on the BNT can also be used to see whether LGG-patients do indeed differ from CVA-patients. It is hypothesized that the brain of LGG-patients has had time to reorganize slowly and effectively; therefore they show no severe neurological deficits. Since a CVA is not progressive but acute, the brain has not had this long time to adapt to the lesion: the reorganization starts after it is too late. This would be similar to the reorganization in the brain of the LGG-patient starting after the tumor is too large and starts to induce seizures. The reorganization will be fast and therefore less effective than when the brain has had enough time to adapt to the lesion.

We can thus compare the quantitative results on the BNT from the two groups to see whether CVA patients make more errors than LGG patients, as predicted. If not, this might suggest that the reorganization processes do not differ: they will be equally effective.

The use of qualitative errors on the BNT

In an earlier section, it was hypothesized that since the reorganization processes in the brains of LGG- and CVA-patients are so different, it might be the case that the patients do not only differ in the amount of errors they make, but also in the type of errors they make. Anomia can take different forms: a patient can make mostly semantic errors in naming concepts and/or objects, he can mostly make phonemic errors, or maybe he makes mostly unrelated errors, or a combination of the errors above. We can see what kind of errors a patient makes by categorizing the errors made on the Boston Naming Test.

There is no previous research that has compared results on the BNT between CVA- and LGG-patients, or that has qualified results on the BNT of one of these groups. But since the reorganization process is so different in both groups, it is only natural that their errors differ too.

In the brain of LGG-patients, there will have been a slow and effective reorganization before the tumor is discovered. This shows from the fact that most patients with an LGG do not suffer from any severe language problems. But LGG-patients do make errors on the BNT. This could be because in real life, when you are telling something, the other person does not know the exact words you want to say. Therefore, when you cannot think of the name of an object or a concept, you can easily work around it by describing the object or naming something that is closely related to it. In other words: there are many compensation strategies the patient can use when he does not know the correct word. These strategies will be highly developed in LGG-patients, since they have been using them for years. The strategies will show in the errors made on the Boston Naming Test. While in real life descriptions and semantic paraphasias are not seen as erroneous and thus do not indicate a naming deficit, they are counted as errors in the BNT.

The brain of CVA-patients, on the other hand, is not used to not being able to think of the correct name for an object and/or concept. Their compensation strategies will thus not be as effectively developed as in LGG-patients, which will show on the BNT. Not only will the CVA-patient make more mistakes, since there has been a fast and therefore less effective reorganization, they will also make different errors. It could be that they are not able to select the right phonemes, hence producing something as ‘pinx’ for ‘sfinx’, or that they make up totally new words, not related to the intended object at all (‘zagaza’ for ‘pretzel’) . It could also be that they can give no answer at all. This also shows in the fact that neurological deficits are much more severe in CVA-patients than in LGG-patients: CVA-patients cannot effectively compensate for their loss.

Hypothesis

The hypothesis that is tested in this research is the following:

When a brain lesion is slow-growing as in the case of low grade gliomas, the reorganization is gradual and there is more time for the latent functional areas to adapt to the lesion, thus leading to less and perhaps different errors than patients with acute lesions, where the reorganization has to be fast and is less efficient.

This hypothesis is tested by using quantitative and qualitative results on the BNT. Quantitative results are used within-group (before and three months after the surgery of LGG patients) and between-groups (LGG- and CVA-patients). The within-group results will be used to see whether the brain has been reorganizing for years, or that it only starts to reorganize after the tumor is removed. The between groups results will be used to see whether CVA patients indeed make more errors than LGG patients, as predicted by the hypothesis. Qualitative results are compared between the two patient groups: LGG- and CVA-patients. These results will be used to see if the reorganization processes in the two groups do indeed differ from each other, leading to different error-patterns on the BNT.

Method

Boston Naming Test

The Boston Naming Test is used here, since (as said before) it is a good tool to assess quantitative as well as qualitative anomia. The BNT also has some weaknesses, though. According to Yochim et al. (2009), the BNT is highly correlated with education and it can be influenced by cultural assimilation. It has also been said that the decrease in frequency of the pictures is not strongly correlated with the difficulty of the items and that the items are sometimes misperceived by patients (a pretzel could be seen as a snake). The last disadvantage is that it can take long to administer the BNT.

Yochim et al. (2009) suggest the NAB (neuropsychological assessment battery) naming tests as a (better) alternative to the BNT. There are also other alternatives (like parts of the Western Aphasia Battery and the Akense Afasie Test), but the BNT stays the most widely used naming test in neuropsychological assessments. Since it is so widely used, there are a lot of normative data to compare results with, so one can draw valid conclusions from them. That is why the BNT is used in this research: we have to compare within the group of LGG patients, but also between groups (LGG-patients versus CVA-patients).

Subjects

The Boston Naming Test is administered from 40 patients with a low grade glioma (N1=40). All patients have some degree of naming problems, so we can assume the tumor is located in or near an expressive language center. The LGG-patients are tested twice: once before the operation and once three months after the operation. Next to the LGG-patients, 20 CVA-patients are assessed with Boston Naming Test (N2=20); they have taken only one BNT in the first 4 months post onset.

Error-types

To test whether errors of LGG-patients differ from the errors CVA-patients make, the results have to be qualified; different error-types should be distinguished. To this end, a classification of error types, based on the classification used by Mariën et al. (1998) is used. This classification differentiates between the kind of errors found in the data in a way that is useful to test the assumption. The mistakes are classified as follows:

1. Semantic paraphasia (related semantic concept: cookie – pretzel)
2. Superordinate concept (generalization: horse – unicorn)
3. Semantic neologism (new name with same meaning: sleeper – bed)
4. Adequate description (good description of the object: statue in Egypt – sfinx)
5. Semi-adequate description (reasonable description: which we played with – abacus)
6. Non-adequate description (wrong description: house in the north-pole – pyramid)
7. Phonemic paraphasia (original name is recognizable, but replacement/removal of sounds telescope - stethoscope)
8. Phonemic neologism (new name with same sounds: obino – domino)
9. Don't know-responses/ no response
10. Unrelated mistake (word has nothing to do with original concept: table – sfinx)
11. Perceptual paraphrase (picture is interpreted as something else: snake – pretzel)
12. Perseveration (name of earlier picture)
13. Meaningless language (the patient speaks, but it means nothing: brabalala)

The hypothesis predicts that patients with a low grade glioma mostly make semantic errors and give (semi-) adequate descriptions. CVA-patients are predicted to give more don't know-responses, but also phonematic paraphasias and meaningless language.

Results

Quantitative results

Pre- and post operative LGG-patients

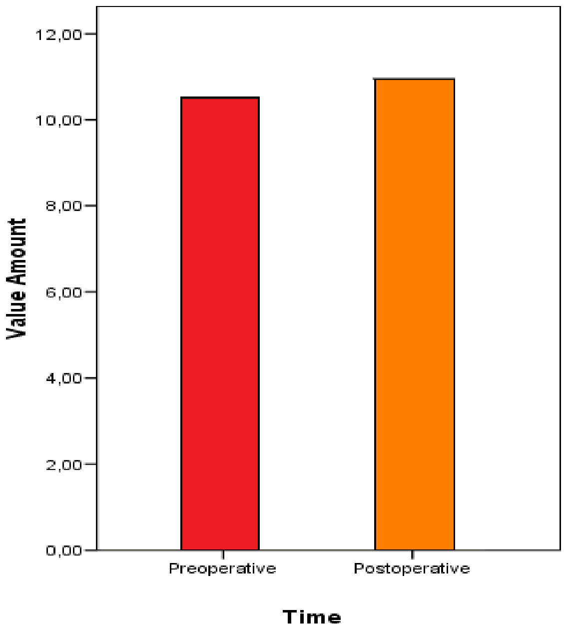

Figure 3: mean amount of mistakes pre- (red) and post-operative (orange) LGG patients

Quantitative results on the Boston Naming Test from LGG-patients before and after resective surgery are compared to see whether the brain has indeed been reorganizing for years, or if the reorganization has only started after the tumor was removed. Before surgery, the mean amount of errors was 10,50 errors (SD = 6.913). After surgery, this was 10,95 errors (SD = 7.555). This means that slightly more errors are made after surgery. A one-sided paired samples T-test at a significance level of $\alpha=0.05$ reveals that there was no significant difference between the two samples ($t(39) = 0.65$, $p>0.05$). This means that the LGG-patients do not make significantly more errors after surgery than before.

LGG-patients versus CVA-patients

To test whether CVA-patients do indeed make more errors on the BNT than LGG-patients do, the LGG-patients' pre-operative quantitative results are compared to the results of the CVA-patients. As figure 4 shows, there is a considerable difference between the amount of errors LGG-patients make and the amount CVA-patients make. The mean amount of errors LGG-patients make is 10,5 errors (SD = 6.913), CVA-patients make 44.55 errors (SD = 10.018) on average. A t-test for independent samples is done to see whether the results differ significantly ($\alpha=0.05$). The t-test shows that there is a significant difference between LGG-patients and CVA-patients ($t(58)= -13{,}66$, $P<0{,}05$). CVA patients make significantly more mistakes on the BNT than LGG patients do.

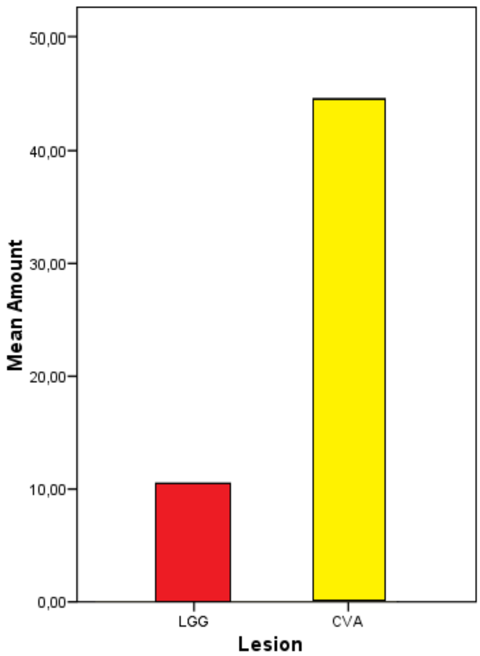

Figure 4: mean amount of mistakes of pre-operative LGG- (red) and CVA-patients (yellow)

Qualitative results

Results on the BNT are categorized to see whether the types of errors LGG-patients make do indeed differ from the types of errors CVA-patients make. Table one shows the amount of mistakes per group per error-type and the corresponding percentages.

Table 1: total amount of mistakes per group on the items and correlating percentages. Significant between-groups differences are indicated with an asterisk.

Error	Pre-operative LGG		CVA	
	Amount	**Percentage**	**Amount**	**Percentage**
1 Semantic paraphasia *	127	*30,09 %*	97	*11,35 %*
2 Superordinate concept *	36	8,53 %	33	3,86 %
3 Semantic neologism *	33	7,83 %	26	3,04 %
4 Adequate description	57	13,51 %	86	*10,06 %*
5 Semi-adequate description	18	4,27 %	53	6,2 %
6 Non-adequate description *	11	2,61 %	59	6,91 %
7 Phonemic paraphasia *	14	3,32 %	148	*17,31 %*
8 Phonemic neologism *	2	0,47 %	96	*11,23 %*
9 Don't know response	102	*24,17 %*	105	*12,28 %*
10 Unrelated mistake *	8	1,90 %	46	5,38 %
11 Perceptual paraphrase *	14	3,32 %	28	2,11 %
12 Perseveration	0	0 %	14	1,64 %
13 Neologism *	0	0%	74	8,65 %
Total	**422**	**100%**	**855**	**100%**

Within groups- results

LGG patients give an erroneous answer in 422 of the 2400 possibilities (17,58%). CVA patients give a wrong answer in 855 of the 1200 possibilities (71,25%). This is a considerable difference, as was also shown in the previous section. Table 1 also shows that LGG-patients make most errors of types 1 (30.09%) and 9 (24.17%); these are semantic paraphasias and don't know responses. CVA-patients make most errors of types 1 (11.35%), 4 (10.06%), 7 (17.31%), 8 (11.23%), 9 (12.28%) and 13 (8.65%); these are semantic paraphasias, adequate descriptions, phonemic paraphasias, phonemic neologisms, don't know responses and neologisms.

A one-way ANOVA ($\alpha = 0.05$) on the amount of errors of LGG-patients does indeed show that there is a significant difference between the types of errors: $F(11, 468) = 25.409$, $P<0.05$. A post-hoc Tukey HSD-test indicates that semantic paraphasias ($\mu = 3.175$) and don't know-responses ($\mu = 2.550$) form a homogeneous subset. The same procedure was also followed for the CVA-patients. Here too, there is a significant difference between the types of errors: $F(12, 247) = 5.062$, $P<0.05$. The most significant homogeneous subset found with Tukeys HSD test consists of semantic paraphasias ($\mu = 4.850$), adequate descriptions ($\mu = 4.300$), phonemic paraphasias ($\mu = 7.400$), phonemic neologisms ($\mu = 4.800$), don't know responses ($\mu = 5.250$) and neologisms ($\mu = 3.700$).

Between-groups results

To test whether LGG-patients differ significantly from CVA-patients on each error-type, the amount of errors per type per person are converted into percentages. The mean percentages per group per error-type are shown in figure one. From figure five, it is obvious that there is a big difference between the mean percentages on certain error-types. To test whether these differences are significant, independent t-tests ($\alpha = 0.05$) on all error-types were done.

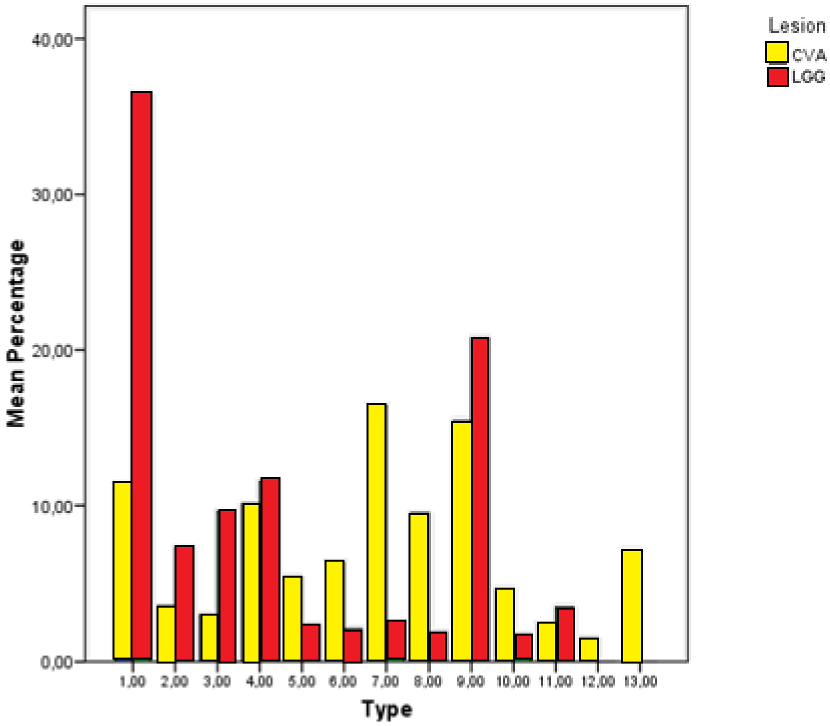

Figure 5: mean error-percentages per group per error-type.

<u>Error type 1: Semantic paraphasia</u>

On average, LGG-patients make more semantic paraphasias ($\mu = 36.43$, SD = 20.21) than CVA-patients ($\mu = 11.39$, SD = 8.99) do. This is a significant difference ($t(57.5) = 6.63$, $P<0.05$).

<u>Error type 2: Superordinate concept</u>

Again, LGG patients make more errors of this type ($\mu = 7.29$, SD = 20.20) than CVA-patients ($\mu = 3.58$, SD = 3.682) This too is a significant difference ($t(55.56) = 2.158$, $P<0.05$).

<u>Error type 3: Semantic neologism</u>

As seen in figure one, LGG-patients make more errors of this type ($\mu = 9.62$, SD =12.99) than CVA-patients do ($\mu = 3.02$, SD = 3.15) . Again, this is a significant difference ($t(47.39) = 3.04$, $P<0.05$).

<u>Error-type 4: Adequate description</u>

For this error-type, the mean percentages of LGG- patients ($\mu = 11{,}5543$, SD = 13.23) and CVA-patients ($\mu = 10.11$, SD = 10.70) do not differ very much. There is no significant difference ($t(58) = 0.423$, $P>0.05$).

Error-type 5: Semi-adequate description
For this type, CVA-patients make more errors (μ = 5.46, SD = 6.98) than LGG-patients do (μ = 2.38, SD = 4.68), although this is no significant difference (t(27.82) = -1.785, P>0.05).

Error-type 6: Non-adequate description
Again, CVA-patients make more errors of this type (μ = 6.40, SD = 7.42) than LGG-patients do (μ = 2.12, SD= 4.80). This is a significant difference (t(27.202) = -2.35, P<0.05).

Error-type 7: Phonemic paraphasia
There is a large difference in average percentage of errors of this type between CVA-patients (μ = 16.44, SD = 11.17) and LGG-patients (μ = 2.55, SD= 5.93). As expected, this is a significant difference (t(24.5) = -5.202. P<0.05).

Error-type 8: Phonemic neologism
Here again, there is a large difference between the CVA-patients (μ = 9.51, SD = 8.44) and the LGG-patients (μ = 1.89, SD = 7,44). This is a significant difference (t(58) = -3.577, P<0.05).

Error-type 9: Don't know-response
LGG-patients give on average more of these responses (μ = 20.77, SD = 18.62) than CVA-patients do (μ = 15.43, SD = 17.50). Nevertheless, this is no significant difference (t(58) = 1.066, P>0.05).

Error-type 10: Unrelated mistake
CVA-patients make more errors of this type (μ =4.688, SD = 17.50) than LGG-patients do (μ = 1.75, SD = 5.02). This is a significant difference (t(58) = -2.031, P< 0.05).

Error-type 11: Perceptual paraphrase
LGG-patients make slightly more errors of this type (μ = 3.51, SD = 6.63) than CVA-patients do (μ = 2.44, SD = 3.63). This difference is not significant (t(58) = 0.673, P>0.05).

Error-type 12: Perseveration
LGG-patients make no errors of this type, while CVA –patients make some (μ=1.50, SD = 3.20). Since LGG-patients made no errors at all, the difference is significant (t(19) = -2.095, P <0.05).

Error-type 13: Neologism
Again, LGG-patients made no errors of this type. CVA-patients made quite a lot (μ = 7.13, SD = 13.51). The difference is again significant (t(19) = -2.359, P<0.05).

To sum up: LGG-patients make significantly more errors on the following error-types: semantic paraphasia, superordinate concept and semantic neologism. CVA-patients make significantly more errors: on non-adequate description, phonemic paraphrase, phonemic neologism, unrelated mistake, perseveration and neologism. LGG- and CVA-patients do not differ on adequate- and semi-adequate descriptions, don't know –responses and perseverations.

Discussion

Interpretation of the results

The Boston Naming Test was used in this research to find out whether progressive and acute brain lesions induce different naming problems. It was hypothesized that since the reorganization in the brain of LGG-patients is slow and thorough, the patients will make less and qualitatively different errors on the BNT than CVA-patients do. The results show that this is indeed the case.

A T-test for independent samples indeed revealed a significant difference in the quantitative results on the BNT: CVA-patients made on average 44.55 (SD = 10.018) errors, while LGG-patients made only 10.5 (SD = 6.913) errors on average. This is a large difference that definitely confirms the hypothesis that CVA-patients will make more errors on the BNT; this might be a result of less effective brain-reorganization.

The next question was if LGG-patient also make qualitatively different errors than CVA-patients do. After categorizing the BNT-errors, it was shown that LGG-patients made most errors on semantic paraphasias and don't know-responses. These errors were also in the most frequent errors CVA-patients made, along with adequate descriptions, phonemic paraphasias, phonemic neologisms and neologisms.

It is strange that 'adequate description' is one of the most frequent errors made by CVA-patients, but not by LGG-patients. This is not what the hypothesis predicted. It was predicted that the errors of LGG-patients would mostly be semantic paraphrases and adequate descriptions, while CVA-patients would not make many of these errors. When the results were converted into percentages, however, there was no significant difference between LGG- and CVA-patients on this point: LGG-patients even made (relatively) slightly more adequate descriptions than CVA-patients did. They also gave more semantic paraphasias, superordinate concepts and semantic neologisms than CVA-patients did. CVA-patients, on the other hand, gave significantly more non-adequate descriptions, phonemic paraphasias, phonemic neologisms, unrelated mistakes, perseverations and neologisms than LGG-patients did.

These results are in line with what was hypothesized: the brain of the LGG-patients has been effectively organizing for years, thus leading to less errors. When the patients do make errors, these reveal that the patients have found an effective way to compensate for them: by using adequate descriptions, semantically related concepts and semantic neologisms they are still able to communicate properly. The lesion of CVA-patients, on the other hand, is acute: leading the brain to reorganize fast and therefore less effective. The patient is thus not as used to not being able to name objects and/or concepts as the LGG-patient is, often leading to less effective compensation strategies or no compensation at all.

It is important to keep in mind, though, that not all LGG-patients were perfectly able to compensate their anomia with effective strategies. For example, 24,7 % of the errors made by LGG-patients were don't know-responses. And on the other hand, 11.35% of the errors CVA-patients made were semantic paraphasias, and 10.06% of their errors were adequate descriptions. The qualitative difference between LGG- and CVA-patients might thus not be as clear cut after all. It might be more of a continuum, rather than two opposite categories.

Overall, though, most of the errors made by LGG-patients show that they are used to their deficit and are able to compensate it by using effective strategies, while most of the errors CVA-patients made were not compensating their deficit, they only revealed it.

Another important consideration is the moment of assessing the BNT for CVA-patients. They have been tested only four months after the stroke, so the brain has only had four months to reorganize; to repair the damage done by the lesion. When they would have been tested at a later point in time, it might be the case that their brains are more reorganized, thus leading to a better compensation for the lesion and less difference between LGG- and CVA-patients.

To summarize the results: it seems that the hypothesis is confirmed: in patients with slow, progressive lesions like low grade gliomas there is enough time for the brain to reorganize effectively, thus leading to less and qualitatively different errors on the BNT than when the brain has to reorganize fast and thus less effective, as is the case in the brains of CVA-patients.

A note on mental lexicon

In the introduction, there was a short introduction on the mental lexicon and how the semantic concepts are represented in the brain. Two theory-types were discussed: one hierarchical model and one 'spreading activation'-model. Both models predicted different naming errors when a patient has an impairment in the mental lexicon: the hierarchical model predicted that the patient would make most superordinate errors (at the basic level, so 'bird' for 'canary'), while the spreading activation model predicted more semantic paraphasias (semantically related concepts). The analysis on the current data cannot give conclusive evidence on what model is correct. Though, we can actually see that there are a lot more semantic paraphasias, both in LGG-patients (μ = 36.43) as in CVA-patients (μ =11.39) than there were superordinate concepts (μ = 7.29 and μ = 3.58 respectively). This might be a hint towards a spreading activation model, but we absolutely cannot know for sure. To research this, at least we have to know if the impairment is at the level of the mental lexicon, and we have to do individual analysis. It will be interesting to use this sort of data to do research on the representation of the mental lexicon.

Limitations and further research

The BNT is used here to explain why different lesions induce different neurological deficits. Patients who made more errors on the BNT were hypothesized to have had less effective reorganization in the brain. It was suggested that the comparison of quantitative results before and after surgery of LGG-patients can be used to assess whether the reorganization process was already going on for years, or that it only started after the tumor was removed. Since there was no significant difference in the amount of errors before and after surgery, this was seen as a confirmation that the reorganization process had not only started when the tumor was removed. The use of the BNT might not be the best way to assess whether functional reorganization has taken place. This can also be done with different functional imaging methods, like fMRI. In fact, Duffau (2005) shows a preoperative fMRI-scan during a language task in a patient with a left dominant LGG, showing a perilesional distribution of language sites in the frontal and temporal operculae and in the left putamen. It can thus be seen before surgery if there has been reorganization in the brain or not; this makes the use of the BNT perhaps unnecessary on this point.

fMRI does not directly show, however, what the consequences of this reorganization are for the patients' functioning. That is the main reason why the BNT is used here: to compare reorganization processes in different types of brain lesions. If it is indeed the case that LGG-patients have a different response-pattern on the BNT than CVA-patients do, then this could be of clinical use. When it is not yet known what type of lesion a patient has and the patient shows naming problems, the patient can be assessed with the BNT. When the results are categorized, they can be compared with norms of different patient-groups and this might give an indication of the type of lesion a patient suffers from.

Of course this is not at all possible yet. To my knowledge, there are no previous studies that have qualified and compared results on the BNT for different patient-groups. That means that the current study is the first to do this and that there are no existing norms. To make this type of assessment of any clinical use, the research must be replicated and extended so that results can be standardized: until now, this has only been done for the quantitative aspect of the BNT.

Perhaps the error-types used in this research were not ideal to differentiate between LGG- and CVA-patients. It might be useful to reduce the error-types to more global-categories, for instance semantic errors, phonemic errors and unrelated errors. The question is, however, if the difference between groups is seen by using these categories, or if the differences are more specific and show only on smaller categories.

There should also be a clear definition of each error-type. Sometimes it was difficult to categorize errors to one specific type, especially between phonemic paraphasia and phonemic neologism. When is the error a paraphasia, and when is it something completely new? This should be clear, especially when more research is done on this topic.

Although this study has limitations, it could form a basis for further research about how qualitative results on the BNT can have value in assessing anomic patients. In combination with other measures as fMRI, it might be used to assess the types of lesion. There is a clear difference between the qualitative errors of patients with slow growing, progressive lesions and the errors of patients with acute lesions and this difference can perhaps be put to use in clinical practice.

Conclusion

The results confirm the hypothesis tested in this study: there *is* a difference in brain-reorganization between LGG- and CVA-patients and this difference shows in the quantitative and qualitative errors the patients make on the Boston Naming Test.

Further research must be done to confirm these results and to make norms for the qualitative results of the BNT. When this is done, perhaps the quantitative and qualitative results can be used in clinical practice to assess (in combination with other methods) what type of lesion a patient suffers from.

Acknowledgements

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