Neurocase, 2014
Vol. 20, No. 2, 192–207, http://dx.doi.org/10.1080/13554794.2012.741258

Routledge
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Sensory-specific anomic aphasia following left occipital lesions: Data from free oral descriptions of concrete word meanings

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The present study investigated hierarchical lexical semantic structure in oral descriptions of concrete word meanings produced by a subject (ZZ) diagnosed with anomic aphasia due to left occipital lesions. The focus of the analysis was production of a) nouns at different levels of semantic specificity (e.g., "robin"–"bird"–"animal") and b) words describing sensory or motor experiences (e.g., "blue," "soft," "fly"). Results show that in contrast to healthy and aphasic controls, who produced words at all levels of specificity and mainly vision-related sensory information, ZZ produced almost exclusively nouns at the most non-specific levels and words associated with sound and movement.

Keywords: Concrete words; Abstract words; Sensory features; Anomic aphasia; Occipital lesion; Semantic specificity; Lexical semantic hierarchy; Visual information.

INTRODUCTION

Occipital lesions and modality-specific word problems

Concrete nouns (e.g., "table") and verbs (e.g., "kick") activate brain regions involved in experiencing their referred objects and actions (Hauk, Johnsrude, & Pulvermüller, 2004; Khader, Jost, Mertens, Bien, & Rösler, 2010; Martin, Haxby, Lalonde, Wiggs, & Ungerleider, 1995; Pulvermüller, Preissl, Lutzenberger, & Birbaumer, 1996; Sabsevitz, Medler, Seidenberg, & Binder, 2005; Shapiro, Moo, & Caramazza, 2006). This activation has been suggested to be either an effect of associative learning where words automatically activate sensory or motor neural circuits (Pulvermüller & Fadiga, 2010) or a post-lexical simulation of the words' associated action (Tomasino et al., 2010). In both cases, it can be expected that lesions in areas involved in sensory processing may result in modality-specific word processing problems. The present study investigated word production in a man (ZZ) diagnosed with anomic aphasia due to occipital lesions, in order to see if the damage to visual areas would selectively affect production of words with visually related semantic content.

Left occipital lesions may lead to a syndrome known as optic aphasia, characterized by difficulties in naming visually presented stimuli, (e.g., pictures, objects and colors), whereas naming stimuli perceived through other sensory modalities

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This research has been supported by grants 421-2009-1773 and 349-2007-8695 from the Swedish Research Council.

(i.e., touch, hearing, taste or smell) as well as naming from verbal definitions is unimpaired (Gainotti, 2004; Girkin & Miller, 2001; Manning, 2000). However, although naming from visual presentation is selectively impaired in optic aphasia, naming from verbal definitions may be more or less successful depending on the sensory modality of their semantic content. At least two case studies indicate that individuals with optic aphasia seem to perform more poorly in tasks involving responding to verbal definitions rich in visual information (Forde, Francis, Riddoch, Rumiati, & Humphreys, 1997; Manning, 2000).

Degree of semantic specificity and visual information

Nouns with a relatively high degree of semantic specificity (e.g., "robin") can be assumed to be more closely related to visual information as opposed to relatively abstract nouns belonging to the same lexical semantic hierarchy (e.g., "animal") (Rosch, 1978). Although the effect of degree of specificity has not previously been investigated in persons with occipital lesions, studies of persons with lesions in other areas suggest that different brain regions are involved in processing words associated with subordinate, basic and superordinate semantic categories. For example, individuals with semantic dementia have shown an advantage in picture categorization using superordinate level words, in contrast to persons with aphasia due to lesions involving frontal or temporoparietal regions, who have been seen to perform better using subordinate level words. Both groups appear to differ from healthy controls, who have been observed to categorize stimuli at the basic level with greatest speed and accuracy (Crutch & Warrington, 2008; Rogers & Patterson, 2007). In semantic dementia, difficulties with processing more specific words can be explained by a loss of amodal semantic representations stored in the anterior temporal lobes (Crutch & Warrington, 2008; Jefferies & Lambon Ralph, 2007; Marques, 2007; Patterson, Nestor, & Rogers, 2007). In aphasia due to occipital lesions, problems with processing more specific words would also be expected; however, the difficulties would instead be assumed to be the result of deficits in activating modality-specific (visual) semantic representations.

The present study

The present study investigated content word production in a man (ZZ) diagnosed with anomic aphasia due to left occipital lesions. ZZ was compared to healthy speakers as well as persons diagnosed with aphasia following lesions in left perisylvian regions. In contrast to previous studies investigating the effect of presentation modality on naming performance, a purely verbal task (orally describing the meanings of concrete nouns) was used in order to see whether ZZ had problems accessing words with visual semantic content. Furthermore, in contrast to testing access to specific target words (e.g., by naming from definitions), word meanings were described freely, making it possible to analyze the lexical semantic content produced in running speech. Free oral descriptions of pictures have previously been used in a case study by Crutch and Warrington (2003) to elicit running speech in an anomic participant, but to the authors' knowledge, the study of free oral descriptions of test words presented orally has not previously been done.

A semantic analysis of the oral word descriptions was carried out where concrete words referring to more specific objects and entities, (e.g., "tulip," "parrot") as well as words directly describing visual properties (e.g., "red," "round") were assumed to be dependent on semantic processing in visual brain regions, whereas words referring to abstract, high-level categories (e.g., "thing," "animal") and words describing other sensory and motor experiences (e.g., "soft," "sweet," "buzz") were assumed to not directly involve the visual cortex. The assumption that specific/subordinate level words used in the descriptions would also involve visual information was based on the fact that these words were hierarchically related to the highly imageable stimulus nouns, which all referred to visually perceivable entities. Following this, *specific words* throughout this paper will refer to nouns whose referents are visually mediated and not to specific words related to other modalities (e.g., words for specific smells, tactile experiences etc.).

Due to ZZ's occipital lesion, he was expected to produce fewer words describing visual properties and nouns associated with specific (subordinate and basic) levels of categorization. In contrast, his production of more general nouns at higher (superordinate) levels of lexical semantic categorization

was expected to be undisturbed. ZZ was also expected to rely on sensory modalities other than vision when processing semantic information associated with concrete nouns. Thus, ZZ was expected to produce fewer words with vision-related meaning components and a relatively greater number of words with meaning components from other sensory modalities as well as words with motor-related meaning components.

METHOD

Participants

The participants in the present study (Table 1) were all native speakers of Swedish and informed consent was obtained from them prior to the test. The aphasic participants were recruited via the Stroke Clinic at Malmö University Hospital.

Case description

ZZ is a right-handed male born in Sweden in 1932. He was admitted to the stroke clinic at Malmö University Hospital on 1 April 2004, and diagnosed with a cerebral infarct due to a posterior cerebral artery stroke. A CT scan performed on 6 April 2004 showed a low attenuating area in the left occipital lobe. Neurological examinations revealed a right-sided homonymous hemianopia, but no visual perceptual deficits. Based on language testing after the stroke using PAPAP (Apt, 1997), the Swedish equivalent of the Boston Diagnostic Aphasia Examination and SBP (Apt, 1999), the Swedish equivalent of the Boston Naming Test, he was diagnosed with light to moderate anomic aphasia including semantic dyslexia (alexia without agraphia). ZZ's auditory language comprehension was within normal limits and his speech was fluent, with normal syntax and phonology. He had a mild to moderate anomia with particular difficulties in finding proper names. He produced verbal (semantic) paraphasias. A full evaluation of his naming abilities could not be made since he discontinued the SBP test before it was completed.

In a previous study on word associations (Mårtensson, Roll, Apt, & Horne, 2011), ZZ was observed to produce mainly associations which were on an abstract superordinate level (13/30) in relation to test words (e.g., *blomkål* "cauliflower"→ *mat* "food," *leopard* "leopard"→ *djur* "animal"). In several cases (7/30) he could not produce any

TABLE 1
Description of participants: occipital aphasic participant ZZ, perisylvian aphasic controls, and healthy controls. All data collection for the present study was carried out during 2009 and 2010

Participant	*Lesion*	*Diagnosis*	*Sex*	*Age*	*Years of education*	*Cause and onset of aphasia*	*Latest CT*
Occipital case							
ZZ	LH Occipital	Anomic aphasia	Male	78	16+	stroke 2004-04-01	2004-04-06
Aphasic controls							
1a	LH Temporo-parietal	moderate Wernicke aphasia, light anomia	Female	74	9	stroke 12003-08-12 stroke 2 (same region) 2004-01-01	2003-08-13
2a	LH Frontal	mild Broca aphasia	Male	42	12	cerebral hematoma from aneurysm 1990 operation January 1991 increasing symptoms January 1992	1992-02-12
3a	LH Fronto-parietal	mild-moderate Broca aphasia	Female	43	12	cerebral infarct, thrombosis after traffic accident 1989-04-23	1989-05-19
4a	LH Frontal	mild Broca aphasia	Female	36	12	stroke 2007-01-04	2007-01-04
Healthy controls							
1b			Female	80	9		
2b			Male	43	9		
3b			Female	43	12		
4b			Female	31	12		
5b			Male	86	16+		

association at all for concrete nouns and the remaining responses (9/30) were not categorically related to the test word.

Materials and procedure

Participants were instructed to freely describe orally the meanings of orally presented Swedish nouns in as much detail as possible and told that there were no right or wrong answers. This approach was based on a method used by Barsalou and Wiemer-Hastings (2005), who investigated descriptions of abstract and concrete concepts in healthy individuals. Compared to traditional methods such as naming tests, this method has the advantage that the participants have the possibility to respond more freely, thus providing the opportunity to gain insight into different strategies used to express word meanings involving different levels of semantic specificity as well as different sensory features.

Since the material analyzed in the present study was part of a larger study investigating the effect of words' imageability and emotional arousal, the concrete test nouns were presented mixed with abstract and emotional nouns. Responses to 20 concrete nouns, i.e., nouns rated high in imageability (M = 641, SD = 26) (Mårtensson, Öberg, & Horne, manuscript, 2012, see Appendix A) were analyzed. The test words included mainly visually related nouns (e.g., *fjäril* "butterfly," *näckros* "waterlily") as well as nouns which, in addition to their salient visual features, could also be experienced through other sensory modalities (e.g., *varg* "wolf" [sound] and *hasselnöt* "hazelnut" [touch, taste] [Appendix A]). An approximately equal number of test words denoting living and non-living things were included (cf. Warrington, 1984).

The oral descriptions were recorded with a Marantz PMD660 Portable Solid State Recorder. Approximately one minute of speech produced as response to each test word was orthographically transcribed. Nouns belonging to the same lexical-semantic hierarchy as the test word were then analyzed with respect to their degree of specificity and content words describing the test word's semantic properties were analyzed with respect to their sensory and motor features.

Data analysis

Content words (adjectives, verbs and nouns) in the participants' descriptions were coded according to a coding scheme reflecting five degrees of semantic specificity. These are summarized below in Table 2. Words were coded as Level 1, the most specific level, if they were associated with specific sensory or motor related properties of the test words' referents. Levels 2–5 correspond to increasingly higher levels of semantic generality (levels of categorization in Rosch's (1978) terms) in relation to Level 1. To allow for a more fine-grained analysis, the properties on one were further coded as regards the modality of their sensory and motor-related meaning components (vision, sound, touch, taste/smell, movement. See Appendix B and C for examples).

Descriptive data analysis was carried out using SPSS. ZZ's and control participants' words coded for different levels of specificity were compared using Fisher's exact tests.[1] The more specific levels (1–3), assumed to be associated with sensory and motor features, were compared to the more general levels (4–5), assumed not to be associated with sensory and motor information. The distribution of words related to different sensory and motor modalities was also investigated using two-tailed Fisher's exact tests. A qualitative analysis of responses was also made.

[1] Carried out using http://faculty.vassar.edu/lowry/tab2x2.html

TABLE 2
Examples of a test word and response words at different levels of semantic specificity (level 1 = most specific, level 5 = most general)

Test word	*Response*	*Level*
wolf	(is) grey/(has) fur/howls/(can) bite	1 property/part-of-whole
	(looks like a) German shepherd	2 subordinate level; perceptually detailed
	(looks like a) dog	3 basic level; perceptual Gestalt image possible to form
	(is a) predator	4 directly superordinate level; no or diffuse perceptual image
	(is an) animal	5 higher superordinate level; no or diffuse perceptual image

RESULTS

Levels of semantic specificity

The majority of the test words were described by ZZ using words at the superordinate, most general level 5, e.g., *mat* "food," *djur* "animal," *växt* "plant," *art* "species," *sak* "thing," *instrument* "instrument" or *apparat* "device." For the test words *diamant* "diamond," *silver* "silver," *tegelsten* "brick," ZZ could not access any information at all, and responded only by saying that he did not know those words or that he could not say anything about them. He produced very few nouns at the basic level 3 (*hus* "house" and *blomma* "flower"). The word *blomma* "flower" was produced only after having repeated the test word *näckros* "waterlily" together with other types of flowers in a song line several times (Appendix D).

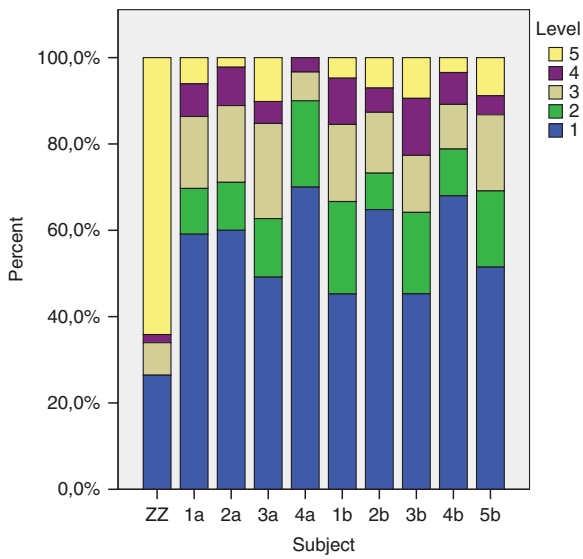

Figure 1a. Distribution of word tokens at different levels of semantic specificity (% of coded words produced by the individual subjects; ZZ = occipital; 1a–4a = aphasic controls; 1b–5b = healthy controls). Level 1 = most specific, level 5 = most general.

Whereas 45–70% of the coded words produced by healthy as well as aphasic controls were at the lowest level (1 = property/part-of-whole), only 26% of ZZ's were at level 1. However, over 60% of ZZ's coded content words were level 5 (superordinate) words. This difference in distribution between ZZ and controls is visualized in Figures 1a–b. ZZ clearly stands out from the rest with his use of words at relatively high levels of semantic abstractness, mainly at the most general level (5). Comparing the production of words at the more specific, perceptually detailed levels (1–3) with words at the more general levels (4–5) using two-tailed Fisher's exact tests, ZZ was seen to differ significantly from each of the healthy and aphasic controls. Whereas all controls produced more words at the lower levels, ZZ produced more words at the

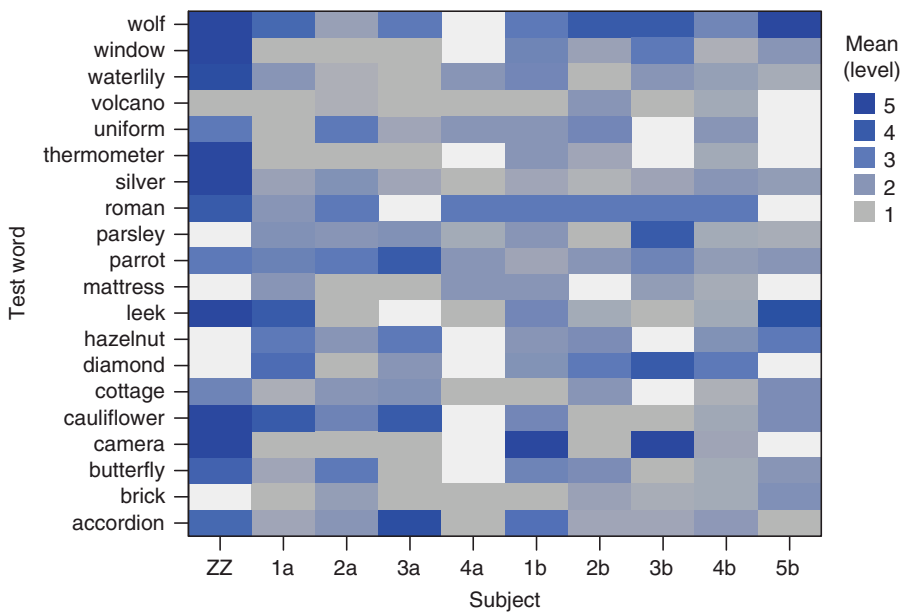

Figure 1b. Heat map showing the distribution of mean levels of semantic specificity associated with words produced in descriptions of each test word for the individual subjects (ZZ = occipital; 1a–4a = aphasic controls; 1b–5b = healthy controls). Level 1 = most specific, level 5 = most general. White cells indicate that no words coded as level 1–5 were used in the description.

TABLE 3
Average number of types and tokens of produced content words for each test item

	Types		*Tokens*		
Participant	*Mean*	*SD*	*Mean*	*SD*	*Type/Token Ratio*
ZZ	*1.35*	*1.309*	*2.65*	*2.796*	*0.51*
1a (temporo-parietal)	2.75	1.860	3.30	2.105	0.83
2a (frontal)	3.40	2.393	4.50	3.591	0.75
3a (frontoparietal)	1.95	1.669	2.95	2.212	0.66
4a (frontal)	1.35	1.496	1.50	1.701	0.90
1b	3.40	2.303	4.20	3.205	0.81
2b	2.90	2.100	3.55	2.819	0.82
3b	2.05	1.820	2.65	2.346	0.77
4b	8.40	3.648	10.15	3.870	0.83
5b	2.65	3.048	3.40	3.761	0.78

higher levels ($p < .0001$). ZZ produced relatively few related content word types per token (see Table 3).

Some of ZZ's responses which contain nouns from the same lexical semantic hierarchy as the test word were qualitatively different from the other responses and were thus excluded from the quantitative analysis. They are listed in Appendix D below, together with a motivation as to why they were excluded. In one case (example 1, Appendix D), ZZ produced a word belonging to the wrong superordinate category, *växt* "plant" as a response to the test word *fjäril* "butterfly," but at the same time produced a correct motor-related property, *kan flyga* "can fly." He also in some cases produced nouns at low levels of specificity that were embedded in song lines (examples 2–3, Appendix D) or in lexicalized phrases (example 4, Appendix D). This was the case for all subordinate level words he produced.

Modality of word properties

As a follow-up analysis, all words coded as being at the most detailed level (1) of specificity were subjected to a more fine-grained analysis in order to see which sensory and/or motor properties they expressed. ZZ produced a total number of 14 content word tokens (only nine different words) which were coded as belonging to level 1 (see Appendix C).

Figure 2 shows the distribution of sensory and/or motor features in relation to the total number of features represented in each participant's word production. ZZ produced words whose meaning can be decomposed into a greater proportion of sound-related features (78.6%) than vision-related features (35.7%). This pattern differed from the aphasic as well as healthy controls, who all produced words associated with more vision-related than sound-related semantic features. Two-tailed Fisher's exact tests showed significant differences between ZZ and eight of the nine controls ($p < .005$) as regards the distribution of visual- and auditory-related features. In control 2b, although his production was associated with a larger number of visual than auditory features, as was the case with the other controls, this difference did not reach significance compared to the feature distribution of ZZ ($p > .05$)[2]. Furthermore, ZZ produced a greater number of movement-related words (42.9%) than any other participant, relatively few words whose meaning contains features related to tactile experience (21.4%), and no words related to taste or smell. For the controls, the second most frequent semantic modality characterizing their analyzed words was touch, whereas words involving sound-related meaning components were relatively few and words related to taste or smell were rare.

When the cases where ZZ's words with sensory or motor related features are put in context, it

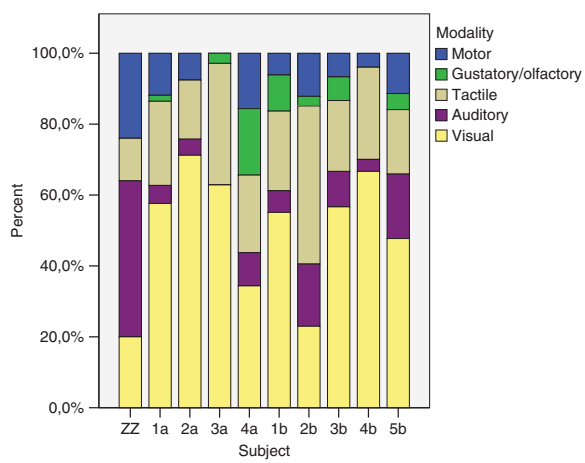

Figure 2. Distribution of sensory and motor meaning components associated with the most specific words produced by individual subjects (ZZ = occipital; 1a–4a = aphasic controls; 1b–5b = healthy controls) expressed as percent of a particular sensory or motor feature in relation to each subjects' total number of features associated with level-1 words.

[2]Looking outside the visual/auditory comparison, it can be seen that control 2b actually produces mainly touch-related words. This differs from the rest of the controls, who all produce mainly vision-related words.

can be seen that the descriptions are rather vague, although ZZ does provide some sensory and motor based information. For example, he describes a "parrot" as an animal which "*squeaks*," "*says something*," "has a certain *sound* or *euphony*," and that a "volcano" is something that "*explodes*" or "*sounds*." Further examples are listed in Appendix E together with responses provided by control participants.

DISCUSSION

Sensory and motor related meaning properties

Despite the instructions to provide as much information as possible about the test words, ZZ produced very few words associated with sensory and motor features, indicating severe difficulties with this level of specificity. Looking at the distribution of feature modalities, he produced mostly sound-related words, with the next largest category being movement-related words, and only rarely words with vision-related meaning components. This differed from the healthy as well as aphasic control participants, who produced predominantly words with vision-related features, with the exception of one healthy control (2b), who produced mostly words with touch-related features. Further differing from the control participants, whose second most commonly produced meaning feature was touch, ZZ produced relatively few words with touch-related features. A possible explanation for the controls' production of relatively many words with touch-related features as well as ZZ's relatively sparse production of them is that words which are strongly vision-related are also often strongly related to touch (Lynott & Connell, 2009).

The auditory features associated with ZZ's production provided fragmentary information about the meanings of the test words, but this was in most cases not enough to result in accurate descriptions (see e.g., responses for "volcano" and "parrot" in Appendix E). Somewhat similarly, the phrase *kan flyga* "can fly" was produced as response to the test word *fjäril* "butterfly," although "butterfly" was referred to as a "plant," suggesting that he had only partial access to the word's meaning. The ability to fly was the only specific information about butterflies he could provide, possibly because the flight of a butterfly has movement-related semantic features in addition to visual features.

The most accurate descriptions produced by ZZ were those which included more abstract information or knowledge about what objects are used for, e.g., that a thermometer is used to measure temperature (see Appendix F for full descriptions). It could thus be expected that even though ZZ's performance on concrete word descriptions was hampered due to occipital lobe damage, he could nevertheless be able to produce more detailed, normal descriptions for less concrete words, e.g., emotional and abstract words.

In order to obtain some indication as to whether ZZ's descriptions of emotional and abstract test words could be judged to be relatively normal in comparison with his descriptions of concrete words, we carried out a follow-up test in which we asked 12 participants to guess which words the descriptions were about. This was done for descriptions produced by ZZ and control 5b who matches ZZ most closely in age and education level. All occurrences of target (test) words in the descriptions were hidden. Results showed that ZZ's concrete word descriptions led to correct responses in significantly fewer cases (35/120) in comparison to control 5b's descriptions (86/120) ($c^2 = 43.353$, $p < 0.001$, df = 1). In contrast, the accuracy of guessing correct target words for ZZ's descriptions of emotional and abstract words did not differ significantly from the target word guesses for 5b's descriptions (emotional words: ZZ: 87/120, 5b: 86/120; abstract words: ZZ: 60/120, 5b: 72/120, ($c^2 = 2.424$, $p = 0.153$, df = 1)). These results can be related to the case study of Crutch and Warrington (2003), where, using a picture-description task, an individual with occipitotemporal lesions showed well-preserved propositional speech and abstract vocabulary, although suffering from severe anomic aphasia.

Taste and smell-related words were not used by ZZ and only to a minor degree by some of the controls. The sparse use of the olfactory and gustatory modalities may be due to the fact that the smells and tastes associated with the test nouns (vegetables, food, flowers, see Appendix A) are difficult to describe in terms of taste or smell; for example, it may be difficult to say what a hazelnut tastes like, other than that it tastes like hazelnut.

Since the material investigated in the present study was originally recorded for other purposes (comparing descriptions of abstract, emotional and concrete test words), the concrete part of the test was not designed to include words with a systematic variation in their associated sensory modalities.

Nevertheless, there was a variation in the stimuli with some test words denoting entities which can be experienced through more than the visual modality (e.g., *dragspel* "accordion," *parrot* "papegoja," *blomkål* "cauliflower"). Although the test words' sensory related modalities should ideally have been systematically varied, a clearly different semantic feature pattern could still be found in ZZ's word descriptions as compared to all other participants.

Considering that the test words were concrete nouns with high imageability ratings, a strong association with visual information was expected to be reflected in the word descriptions as seen in the controls. ZZ's lack of vision-related words and relative focus on sound and movement is consistent with the hypothesis that his occipital lesions would make visual semantic information difficult to access, whereas information from other modalities would be expected to remain more accessible.

Degree of semantic specificity

ZZ produced almost exclusively words coded for the highest, most general levels of semantic categorization (4–5). This pattern differed clearly from healthy as well as aphasic controls, whose word descriptions contained words at all levels of semantic specificity, including a large number of subordinate and basic level words. ZZ only produced subordinate level (2) words in song lines or lexicalized phrases (see Appendix D) which suggests that he is able to access their lexical forms in these specific contexts. There is no evidence, however, that he is able to explain their semantic content or that he would use these subordinate level words spontaneously. Results further showed that the largest proportion of words produced by all controls involved meanings at the most specific level (1 = sensory or motor properties), a pattern which can probably be explained by the nature of the task, i.e., to provide as much information about the meaning of each test word as possible. The fact that the task encourages production of specific descriptions makes the absence of detailed low-level information in ZZ's responses even more striking. It could be argued, however, that speakers might tend to start their descriptions with general information and then move on to more specific information, and that the reason for ZZ's high levels of generality is that he simply produces word descriptions with less information, thus staying at the general level. However, when measuring the average level of the first word related to the test word produced for each test item, controls were found to start out at mean levels close to subordinate (level 2) and basic (level 3) (M = 1.88–3.05), whereas ZZ was found to start out by producing words at the highest mean level (M = 3.73), closer to a superordinate level.

When comparing ZZ to the control participants, it could perhaps be thought that his high level of education contributes to his more abstract way of describing things. The control participants were of varying ages and levels of education with the majority of them being younger and with a lower level of education than ZZ. However, the statistical comparison between ZZ and control 5b (see Figure 1), who matches ZZ in age and level of education, showed that 5b responded in a manner similar to the other controls and differed significantly from ZZ. Furthermore, the concrete words used in the study are unlikely to be unfamiliar to any adult speaker of Swedish (mean rated familiarity = 568, sd = 49). Considering this, we tend not to think that ZZ's results are influenced to any considerable degree by his relatively high age and education level.

CONCLUSIONS

Previous studies have shown that individuals with occipital lesions have difficulties accessing words related to the visual modality (Gainotti, 2004; Manning, 2000). In these studies, the effect of different modes of presentation (e.g., visual/tactile/verbal) was investigated. In the present study, a man (ZZ) with occipital lesions was shown to have selective difficulties with words with visual-related meanings, even though the stimuli were only presented verbally. In descriptions of concrete word meanings, ZZ exhibited a unique pattern producing mostly words with a low degree of lexical semantic specificity. At the level of sensory and motor related properties, ZZ produced very few vision-related words and a larger proportion of sound- and movement-related words. These results support the idea that not only the mode of presentation can affect task performance, but also the degree of visual semantic content in verbally presented stimuli (Forde et al., 1997; Manning, 2000). To the authors' knowledge, this question has not been systematically investigated in previous studies of persons with occipital lesions.

Original manuscript received 15 May 2012
Revised manuscript accepted 5 October 2012
First published online 19 February 2013

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APPENDIX A

List of concrete test words and possible associated sensory and motor parameters

Swedish	*English*	*Imageability*	*Familiarity*	*Vision*	*Sound*	*Touch*	*Taste/smell*	*Movement*
fjäril	butterfly	679	626	x	–	(x)	–	x
varg	wolf	647	584	x	x	(x)	–	x
papegoja	parrot	658	558	x	x	(x)	–	x
stuga	cottage	637	621	x	–	x	–	–
kamera	camera	653	642	x	x	x	–	–
blomkål	cauliflower	642	579	x	–	x	x	–
dragspel	accordion	658	532	x	x	x	–	x
näckros	waterlily	668	458	x	–	(x)	–	x
termometer	thermometer	663	568	x	–	x	–	–
hasselnöt	hazelnut	611	547	x	x	x	x	–
fönster	window	637	642	x	–	x	–	x
roman	novel	568	558	x	–	x	–	(x)
purjolök	leek	647	595	x	–	x	x	–
diamant	diamond	621	532	x	–	x	–	–
madrass	mattress	642	600	x	–	x	–	–
uniform	uniform	642	479	x	–	(x)	–	–
vulkan	volcano	632	526	x	x	–	–	(x)
silver	silver	600	589	x	–	x	–	–
persilja	parsley	663	579	x	–	x	x	–
tegelsten	brick	642	553	x	–	x	x	–

APPENDIX B

List of words with different levels of specificity (1 = most specific, 5 = most general) in test subjects' descriptions of the test word *papegoja* "parrot"

Subject	*Group*	*Swedish word*	*English translation*	*Level*
ZZ	occipital	djur	animal	5
ZZ	occipital	djuret	the animal	5
ZZ	occipital	djur	animal	5
ZZ	occipital	djur	animal	5
ZZ	occipital	djur	animal	5
1a	temporoparietal	fågel	bird	3
1a	temporoparietal	färger	colors	1
1a	temporoparietal	djur	animal	5
1a	temporoparietal	fåglar	bird	3
1a	temporoparietal	fågel	bird	3
2a	frontal	fågelart	bird species	3
2a	frontal	(fågel)arter	bird species	3
2a	frontal	djur	animal	5
3a	frontal	kookaburra	kookaburra	2
3a	frontal	djur	animal	5
3a	frontal	djur	animal	5
4a	frontal	fågel	bird	3
4a	frontal	aror	macaws	2
4a	frontal	nymfparakit	cockatiel	2
1b	control	ara	macaw	2
1b	control	kea	kea	2
1b	control	fjädrarna	the feathers	1
1b	control	färger	colors	1
1b	control	stora	big	1
1b	control	fåglar	birds	3
1b	control	gul	yellow	1
1b	control	kanariefågel	canary	2
1b	control	fåglarna	the birds	3
1b	control	stor	big	1
1b	control	blå	blue	1
1b	control	gul	yellow	1
2b	control	sällskapsdjur	pet	5
2b	control	djur	animal	5
2b	control	färgglada	colourful	1
3b	control	fågel	bird	3
3b	control	färger	colors	1
3b	control	fågel	bird	3
3b	control	djur	animal	5
4b	control	fågel	bird	3
4b	control	färgglad	colourful	1
4b	control	grön	green	1
4b	control	stor näbb	big beak	1
4b	control	fåglar	birds	3
4b	control	fågel	bird	3
4b	control	hård näbb	hard beak	1
4b	control	färger	colors	1
4b	control	sorter av (papegoja)	kinds of (parrot)	3
4b	control	arapapegoja	macaw	2
5b	control	kanariefåglar	canaries	2
5b	control	fåglar	birds	3
5b	control	djur	animals	5

APPENDIX C

ZZ's total production of words with sensory or motor related features. Presence/absence of sensory and motor meaning components are specified with 1/0, respectively

Test word	*Response word*	*No. response tokens*	*Vision*	*Sound*	*Touch*	*Taste/smell*	*Movement*
stuga-"cottage"	*mindre*-"smaller"	2	1	0	0	0	0
vulkan-"volcano"	*sprängs*-"explodes"	2	1	1	0	0	1
vulkan-"volcano"	*hörs*-"sounds"	1	0	1	0	0	0
fjäril-"butterfly"	*flyga*-"fly"	1	1	0	0	0	1
dragspel-"accordion"	*spela*-"play"	3	0	1	1	0	1
papegoja-"parrot"	*piper*-"squeaks"	1	0	1	0	0	0
papegoja-' "parrot"	*säger*-"says"	2	0	1	0	0	0
papegoja-"parrot"	*ljud*-"sound"	1	0	1	0	0	0
papegoja-"parrot"	*välljud*-"euphony"	1	0	1	0	0	0

APPENDIX D

Examples of content words belonging to the same lexical semantic hierarchy as the test word which were not included in the analysis. Pauses are marked with "#"

1. Wrong superordinate (level 5) category: Test word *fjäril* "butterfly" categorized as *växt* "plant" instead of *djur* "animal" or *insekt* "insect"	
det är en **växt** eller en # en # ja **växt** en en # som som **flyger** # en **växt** som en **växt** som kan **flyga** # en fjäril # en **art** som jag inte riktigt kan definiera # hur den **arten** är för jag är inte någon # vidare botaniker # men # det är en **växt** av något slag.	it is a **plant** or a # a # yes **plant** one one # that that **flies** # a **plant** that a plant that can **fly** # a butterfly # a **species** which I can't really define # what that **species** is like because I'm not a very good botanist # but # it is a **plant** of some kind.
2. Subordinate/level 2 words (*violin* "violin," *klarinett* "clarinet") produced in a song line beginning with the test word *dragspel* "accordion" (*dragspel, fiol och klarinett*-"accordion, violin and clarinet"). ZZ recites the song line. It is, however, not totally correct, since it should end with "mandolin" instead of "clarinet."[3]	
dragspel är # någonting som man kan utöva # **spela** # en # vad heter det # ett # ja # dragspel # <***dragspel fiol och klarinett***> heter det i visan # <***dragspel fiol och klarinett***> # nej # dragspel alltså # ett # vad heter det # ett **spel** # **spel** # en **spel** # ett **spel** som man kan **spela** # jag vet hur det ser ut och så vidare men jag kan inte precis definiera det med ord # dragspel # ett **spel** som man kan **spela** # ja.	accordion is # something that you can perform # **play** # a # what is it called # a # yes # accordion # <***accordion violin and clarinet***> the song says # <***accordion violin and clarinet***> # no # so accordion # a (thing to) **play** # (thing to) **play** # a (thing to) **play** that you can **play** # I know what it looks like and so on but I can't really define it with words # accordion # a (thing to) **play** that you can **play** # yes.
3. Subordinate/level 2 words (*blå viol* "blue violet," *gullviva* "cowslip") produced in a song line including the test word *näckros* "waterlily" ("cowslip, waterlily and blue violet"). Note that: (a) again, the song line ZZ produces is not the original one, which is "cowslip, almond blossom, catsfoot and blue violet"[4] thus *not* including the test word "waterlily" (b) ZZ produces the basic level word *blommor* "flowers" after having repeated this song line a couple of times (also singing and humming it).	
<***näckros och blå viol***> # <***gullviva näckros och blå viol***> # näckros # det är alltså en en # ja <***gullviva näckros och blå viol***> # kan du den? # näckros är alltså en ett # någonting som växer # ett en **växt** # som # ja # ja # det är en **växt** # den förekommer just i den visan # <***gullviva näckros och blå viol***> # det var näckros va? # det är en **växt** # en # ett # en # ja vad ska vi kalla det # näckros # det är ett positivt namn på en **växt** # på en **växt** som som har **blommor.**	<***waterlily and blue violet***> # <***cowslip waterlily and blue violet***> # waterlily # so it is a a # well # <***cowslip waterlily and blue violet***> # do you know that one? # so waterlily is a a # something that grows # a a **plant** # that # yes # yes # it is a **plant** # it occurs in that particular song # <***cowslip waterlily and blue violet***> # it was waterlily right? # it is a **plant** # a # a # a # yes what should we call it # waterlily # it is a positive name for a **plant** # for a **plant** that has **flowers**.
4. Subordinate/level 2 word *guld* "gold" produced in an lexicalized phrase beginning with the test word *silver* "silver" (*silver och guld* "silver and gold").	
silver # <***silver och guld***> # det är ja vad är det för någonting # <***silver och guld***> # det är # aj aj # det är så svårt med orden # ja ja # <***silver och guld***> # silver är # en **egenskap** hos # det är att # det är en # att # en **sak** tillhör # har visst # ett visst en viss **egenskap** # att vara silver # ja jag vet inte # jag kan inte säga.	silver # <***silver and gold***> # it is well what is it # <***silver and gold***> # it is # oh oh # it is so difficult with the words # well well # <***silver and gold***> # silver is # a property of # it is to # it is a # that " a **thing** belongs # has certain # has a certain a certain **property** # to be silver # well I don't know # I can't say.

[3] The original song line is *dragspel, fiol och mandolin*–"accordion, violin and mandolin," from the song "Fritjof och Carmencita" by Swedish composer Evert Taube.

[4] The line is from the song "Sjösala vals," also by Swedish composer Evert Taube; Swedish lyrics "gullviva, mandelblom, kattfot och blå viol."

APPENDIX E

Descriptions containing sensory and motor related words produced by occipital aphasic ZZ as well as aphasic and healthy controls. Pauses are marked with "#"

Test word	*Response ZZ*	*Response perisylvian aphasic control (1a)*	*Response healthy control (5b, 2b, 1b)*
stuga- "cottage"	stuga # det är en **mindre** bostad höll jag på att säga # stuga är ett hus eller # fast ett **mindre** hus # som # oftast på landet en stuga # ja det är ett hus ja.	med **röda knutar** # nej **vita** och så stugan är **röd** # ja det är ju en **sommarstuga** # det kan vara en annan stuga # **badstuga** med bastu i stuga kan vara väldigt mycket # det kan vara **liten** och trivsam men det kan vara en **stor** flott stuga # så att # det är beroende på vad man har råd och var den ligger [. . .].	5b: [. . .] det är ju den gamla kära svenskheten att ha en **röd liten** stuga och # ha eget hem och så där.
	cottage # it is a **smaller** accomodation I was going to say # cottage is a house or # but a **smaller** house # which # most often in the countryside # yes it is a house yes.	with **red corners** # no **white** and the cottage is **red** # yes that is a **summer cottage** # it can be another cottage # **bathing hut** with a sauna in it cottage can be very many things # it can be **small** and cozy but it can be a **big** fancy cottage # so # it is depending on what you can afford and where it is [. . .].	5b: [. . .] well it is the old dear Swedishness to have a **red little** cottage and # have your own home and so on.
vulkan- "volcano"	vulkan # det är # en # någonting som sker i luften # **sprängs** eller på något sätt det är ofta något som **hörs** # en vulkan i luften # är en något som **sprängs** till exempel # jag vet inte precis vad själva ordet betyder # vulkan.	vulkan # det är Etna som **spottar lava** # så det **rinner** längs ner och # **lavan** täcker # hela byar # folk blir begravda # eller får springa # och blir av med sina hem och anhöriga # det är vulkan # men sedan kan det vara väldigt vackert # när man ser # när det inte händer något utan det bara **poppar upp** # ja.	2b: ja då tänker jag på **berg** och **eld** # enorma krafter # enorm **värme** # folk som har många som har farit illa i det # krafter # ja jag kan inte komma på mer faktiskt det är ju # det är ju folk som har blivit begravda # jag tänker på **lava** och # och sådant där och vulkan alltså det är en enorm kraft # det är ju naturens egna krafter som inte vi kan styra hur gärna vi än vill #.
	volcano # it is # a # something that happens in the air # **explodes** or in some way it is often something that **sounds** # a volcano in the air # is a something that **explodes** for example # I don't know exactly what the word itself means # volcano.	volcano # it is Etna that **spits lava** # so that it **runs** down and # the **lava** covers # whole villages # people are buried # or have to run # and lose their homes and relatives # that is volcano # but then it can be very beautiful # when you see # when it doesn't happen anything but just **pops up** # yes.	2b: well then I think of **mountains** and **fire** # enormous forces # enormous **heat** # people who have many who have been damaged in it # forces # well I can't think of more really it is # it is people who have been buried # I think of **lava** and # and these things and volcano it is an enormous force # it is forces of nature which we can't control no matter how much we want to # .
papegoja- "parrot"	papegoja är en en # ett djur # som # ja # som # jag vet inte hur jag ska beskriva det djuret # det **piper** litegrann ibland sådär # och **säger** någonting # och **säger** någonting # en papegoja # jag vet inte så mycket om djur men # det är ju ett djur i alla fall [. . .] en papegoja är ett djur som ofta har ett visst **ljud** eller **välljud** # som den kan uttrycka sig genom.	det är en grann fågel med många **färger** och # som **skriker** så # men ja # jag tycker om djur # jag tycker även om papegojor # och bara som man kan se på tv från regnskogen # med papegojor # de är så granna så granna och # men jag tycker inte om att de har dem i bur # för fåglar de ska vara ute under bar himmel # [. . .]. it is a pretty bird with many **colors** and # that **screams** so # but yes # I like animals # I also like parrots # and you can see on tv	1b: papegoja # ja # korsordet är det ara eller kia ja # så att jag har aldrig haft en större betydelse av en papegoja # jag tycker de är vackra i **fjädrarna** och vackra **färger** och # men jag är inte sådär överförtjust i **stora** fåglar # jag hade en gul sådan vad hette den för något # kanariefågel # en hane som **sjöng** alldeles väldigt # och de **små** fåglarna är jag betydligt mer förtjust i # jag vet att jag tycker de verkar så **bitska** på något vis alla papegojor

APPENDIX E
(Continued)

Test word	*Response ZZ*	*Response perisylvian aphasic control (1a)*	*Response healthy control (5b, 2b, 1b)*
	parrot is a a # an animal # which # well # which # I don't know how to describe that animal # it **squeaks** a little sometimes # and **says** something # and **says** something " a parrot # I don't know very much about animals but # it is an animal anyway [. . .] a parrot is an animal that often has a certain **sound** or **euphony** # which it can express itself through.	from the rainforest # with parrots # they are so pretty so pretty and # but I don't like that they are kept in cages # because birds they should be out under the open sky # [. . .].	[. . .] ja jag kommer ihåg min svärmor berättade om en god vän som hade en papegoja en **stor stor** papegoja som var **blå** och **gul**. 1b: parrot # well # the crossword puzzle it is macaw or kea yes # so parrots have never meant so much to me # I think they have nice **feathers** and nice **colours** and # but I'm not so find of **big** birds # I had a yellow # what was it called # canary # a male that **sang** very much # and the **small** birds I'm much more fond of # I know I think they seem so **snappish** in some way all parrots [. . .] well I remember my mother-in-law told me about a good friend who had a parrot a **big big** parrot that was **blue** and **yellow**.

APPENDIX F
Responses containing abstract/functional information produced by ZZ and healthy and aphasic controls. Pauses marked with "#"

Test word	*Response ZZ*	*Response aphasic control (4a)*	*Response healthy control (4b)*
termometer- "thermometer"	termometer # det är en apparat genom vilken man kan mäta temperaturen # hos en på ett ställe till exempel # en termometer har man har man för att veta hur många grader det är i ett rum till exempel # så har man en termometer där man kan avläsa det [. . .] det är ett redskap eller instrument där man mäter temperaturen.	termometer # ja # det är en sådan som man mäter temperaturen utomhus # eller det är en sådan som man mäter temperaturen # inomhus # eller så kan man ta det om man har feber # och trettiosju och noll # kan det ju vara # då har vi ingen feber.	termometer är någonting som man tar temperaturen med # på # tror jag # och det finns massor av olika termometrar # det finns till exempel köttermometer som man använder när man ugnsbakar kött # då stoppar man in den i köttet # det finns badtermometrar som man använder i vatten # i havet eller i ett badkar # det finns termometrar som man har inomhus för att mäta innetemperatur och det finns utomhustermometer för att mäta utomhustemperatur # och de kan se ut också i en massa olika utföranden # de kan också vara i plast # de kan också vara i metall # det finns de termometrarna som är digitala # det finns de som är med sådan här # kvicksilver #.

APPENDIX F
(Continued)

Test word	*Response ZZ*	*Response aphasic control (4a)*	*Response healthy control (4b)*
	thermometer # it is a device with which you can measure temperature # at a place for example # you have a thermometer in order to know how many degrees it is in a room for example # then you have a thermometer where you can read it [. . .] it is a device or instrument where you measure temperature.	thermometer # well # it is one of those you measure temperature outdoors # or one of those you measure temperature # indoors # or you can take it if you have a fever # and thirtyseven and zero # it can be # then we don't have a fever.	thermometer is something that you measure temperature with # of # I think # and there are lots of different kinds of thermometers # for example there is meat thermometer that you use when you oven-bake meat # then you put it in the meat # there are bathing thermometers that you use in water # in the sea or in a bath tub # there are thermometers you have indoors to measure indoor temperature and there are outdoor thermometers to measure outdoor temperature # and they can look many different ways # they may also be made of plastic # they may also be made of metal # there are digital thermometers # there are those with this # quicksilver #.
uniform- "uniform"	uniform är # något man har på sig # oftast i anslutning till ens yrkesverksamhet ett plagg som # anger vilken yrkesverksamhet man har.	uniform # en av # eller en # åtminstone hundra man # ska de vara # typ # och # de ska klä sig # exakt likadant # då är det en uniform # kläderna alltså # typ en armé # flotta # polis # men även # läkare # kan lite # brandkår kanske # ja.	uniform är ett klädesplagg # som oftast används # för att identifiera en yrkesroll # till exempel sjuksköterskor har en typ av klädsel # som jag skulle vilja kalla för jobbuniform # uniform kan vara militärens uniform # eller flottans uniform # kännetecknas om man tänker på herrar oftast av kostymliknande # beklädnad # med kostymbyxor och kavaj kanske # sedan finns den i olika färger # en pilot har ju oftast mörkblåa # kläder # kostym # uniform # med sådana här axelgrunkor så man ser att de är piloter #.
	uniform is # something you wear # most often related to your profession a garment that # specifies which profession you belong to.	uniform # one of # or one # at least a hundred men # they should be # kind of # and # they should dress # exactly the same # then it's a uniform # the clothes that is # like an army # navy # police # but also # doctors # can a little # firebrigade maybe # yes.	uniform is a piece of clothing # that most often is used # to identify a professional role # for exemple nurses have one type of clothing # that I'd like to call a work uniform # uniform can be the uniform of the military # or the uniform of the navy # is characterized if you think about gentlemen most often by suit-like # clothing # with suit trousers and a jacket perhaps # then it comes in different colours # a pilot most often has dark blue # clothing # suit # uniform # with these shoulder things so you can see they are pilots #.