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Modelling the meaning of words

Neural correlates of abstract and concrete noun processing

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Abstract

A proposal is outlined for relating linguistic modelling of word meaning in terms of semantic features and frames to a general model of neurocognitive information processing. In the brain, posterior sensory cortices are involved in the processing of visual and other sensory features, while anterior areas are important for selection of contextually relevant information. The proposed model assumes concrete nouns to be fundamentally associated with sensory feature constellations, whereas the interpretation of abstract nouns is more dependent on semantic frames. Word processing in healthy speakers was compared with that of speakers with brain lesions affecting language (aphasia). It was hypothesized that anterior lesions would imply problems with lexical tasks involving abstract nouns, whereas damage to posterior (visual) areas of the brain was expected to lead to disturbances in concrete noun processing. The hypotheses were supported by different patterns of free word associations.

Sammanfattning

Den här uppsatsen ger ett förslag på hur lingvistiska modeller av ordbetydelser, såsom semantiska särdrag och ramar, kan relateras till en allmän modell av neurokognitiv informationsbearbetning. Visuell och annan sensorisk information bearbetas i bakre delar av hjärnan, medan främre hjärnområden är viktiga för att välja kontextuellt relevant information. I modellen som föreslås här antas konkreta substantiv vara intimt förknippade med konstellationer av sensoriska semantiska särdrag, medan tolkningen av abstrakta substantiv är mer beroende av semantiska ramar. Ordbearbetning hos friska försökspersoner jämfördes med ordbearbetning hos personer med hjärnskador som påverkar språk (afasi). Hypoteserna var att främre skador skulle medföra problem med semantisk bearbetning av abstrakta substantiv, medan skador i bakre (visuella) delar av hjärnan förväntades ge störningar i den semantiska bearbetningen av konkreta substantiv. Resultaten från ett ordassociationstest stödjer dessa hypoteser.

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1. Background

1.1 Word meaning and linguistic modelling of meaning

Despite much research on the mental lexicon, many questions remain concerning the neural correlates of word meaning. Considerable work has been done on the linguistic modelling of word meaning in terms of componential analysis of word meaning, with meaning components being referred to as e.g. ‘semantic features’ (Weinreich, 1966) or ‘semantic primitives’ (Wierzbicka, 1992), as well as modelling of larger cognitive structures involved in word processing, e.g. ‘semantic frames’ (Fillmore, 1985), ‘idealized cognitive models’ (Lakoff, 1987) and ‘scripts’ (Schank & Abelson, 1977). In this paper, the term ‘semantic feature’ will be used for the processing of smaller meaning components and ‘semantic frame’ will be used for larger cognitive structures. Although the frame and the feature views sometimes are seen as opponents, both views are compatible with neurocognitive models assuming different levels of information processing in the brain. In the present study, a proposal is made which shows how semantic feature modelling and semantic frame modelling can be integrated by relating them to different levels in a general hierarchical model of information processing.

The focus of the study lies on a comparison of concrete and abstract nouns, of which the latter has not previously been well described in the linguistic literature. In a previous study (Mårtensson, 2008), abstract and concrete noun processing in healthy and aphasic subjects was compared using a multiple-choice test and by measuring access times for free word associations. Results showed greater difficulties with abstract nouns for the participants with anterior lesions, whereas the participant with posterior lesions was more impaired in concrete noun processing. However, no in-depth analysis of the semantic relations of the word associations was carried out. In the present study, such an analysis is made.

1.2 Neurocognitive models of meaning representation

Fuster (2009) outlines a model of neurocognitive information processing where different kinds of meaning representations are assumed to be represented in distributed neural networks[1] (Fig. 1; Tab. 1). Although semantic networks can be formed between neurons in virtually any parts of the brain, lower-level, perceptual networks have nodes in posterior[2] sensory cortices related to visual, auditory and tactile processing (dark areas (1-3, 17, 41) behind the Rolandic fissure (RF) in Fig. 1). Similarly, motion-related information activates the primary motor cortex (dark area (4) directly in front of RF in Fig. 1). The greater the complexity of a perception or memory, the more widely distributed neural activity it is associated with in the model. Higher-level, executive processing is more dependent on

1 In this paper, neural meaning representations will be referred to as ‘semantic networks’. Other terms include ‘memory network’, ‘cognit’ (Fuster, 2009) and ‘cell assembly’ (Pulvermüller, 1999).

2 See appendices 3-4 for a glossary and figures related to brain anatomy.

frontal executive networks (whiter areas in front of RF in Fig. 1), whereas higher-level semantic categorization and conceptualization activate temporoparietal and inferior anterior temporal areas involved in integration of different sensory modalities (whiter areas behind RF in Fig. 1) (Fuster, 2009) Figure 1: Hierarchical organization of semantic networks in anterior and posterior cortices (Fuster, 2009)

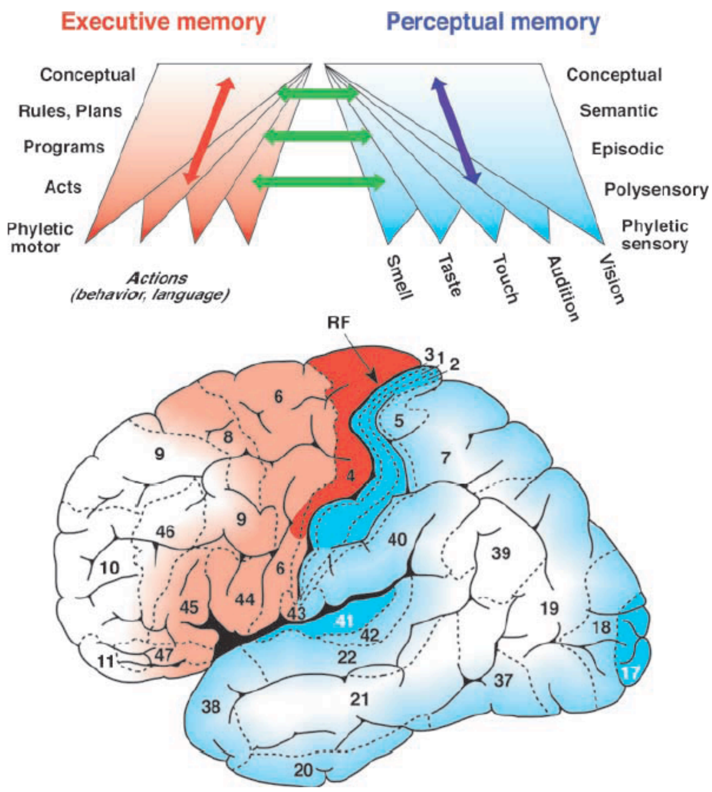


Table 1: Summary of the general model of neurocognitive information processing by Fuster (2009).

Executive memory	**Perceptual memory**
Actions (behaviour, language)	Smell, taste, touch, audition, vision
Phyletic motor (primary motor cortex)	Phyletic sensory (primary sensory cortex)
Acts	Polysensory
Programs	Episodic
Rules, plans	Semantic
Conceptual	Conceptual

Numerous studies, mainly within the fields of neuropsychology and cognitive science, have provided evidence that abstract and concrete words[3] are represented and processed differently in the brain. Neuroimaging data support a greater involvement of posterior, sensory (e.g. visual) areas in concrete word processing (Fig 2) (Martin, Wiggs, Ungerleider & Haxby, 1996; Humphreys, Riddoch &

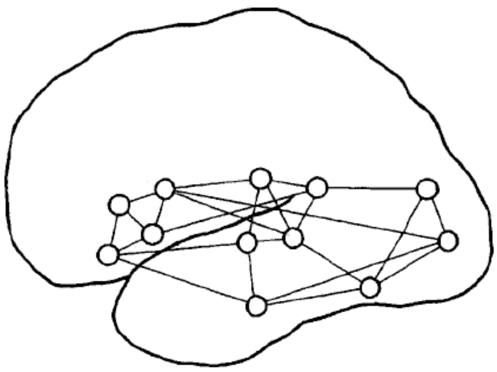
3 In these studies, concrete words are defined as words which to a high degree refer to physical objects and easily evoke mental imagery of sensory experiences, whereas abstract words in contrast do not refer to physical objects and do not easily evoke mental imagery.

Price, 1997; Pulvermüller, 1999) and a more focal activation of anterior 'language' areas[4] (Fig. 3) for function words as well as abstract nouns (Pulvermüller, 1999; Sabsevitz, Medler, Seidenberg & Binder, 2005; Noppeney & Price, 2005; Binder, Westbury, McKiernan, Possing & Medler, 2005).

Further support for the idea that frontal and temporoparietal areas are involved in abstract word processing comes from studies involving speakers with aphasia. Aphasic speakers with anterior lesions are generally found to have greater difficulty in processing abstract words (Hagoort, 1998; Tyler, Moss & Jennings, 1995), whereas posterior[5] damage can be associated with a selective impairment in the naming of visually presented objects and colours (Girkin & Miller, 2001; Gainotti, 2004; Coslett & Saffran, 1992; Forde, Francis, Riddoch, Rumiati & Humphreys, 1997; Luzatti, 2003).

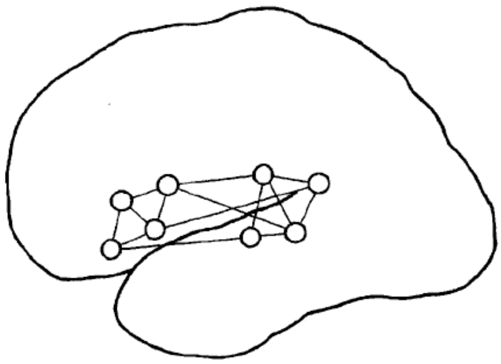
The idea that concrete word processing is more sensory-based has often been interpreted in terms of the cognitive psychological 'dual coding theory' (Paivio, 2007), which assumes abstract words to mainly activate a language-specific (verbal) system, whereas concrete words additionally activate an imagery system[6]. This view is compatible with the hierarchical model of Fuster (2009), but the latter adds the dimension that higher-level semantic networks are assumed to be involved in the processing of abstract information in general, not just language-specific information as in the verbal system described by Paivio.

Figure 2: Schematic distribution of semantic networks of concrete nouns (Pulvermüller, 1999).



4 Associated with e.g. phonological processing and retrieval of sentence context.
5 Occipital/occipitotemporal.
6 Sensory-related information is also assumed to contribute to a general processing advantage of concrete as compared to abstract words, often referred to as the 'concreteness effect'.

Figure 3: Schematic distribution of semantic networks of abstract function words (Pulvermüller, 1999).



1.3 Integrating semantic features and frames in a hierarchical model of word meaning

In this section, it will be shown how modelling of word meaning in terms of semantic features, categories and frames can be related to the hierarchical model of semantic networks described above, with concrete sensory input and motor output at the lowest level, and progressively more abstract knowledge at higher levels. In Table 2, a proposal is made for how cognitive linguistic information at different levels of abstraction can be related to the hierarchy of semantic networks in Fuster's (2009) model of neurocognition. In what follows a description of the linguistic information at the different levels in the hierarchy is presented.

Table 2: Proposed relations between different levels of cognitive linguistic information and the general neurocognitive model by Fuster (2009).

Executive memory	**Perceptual memory**	**Cognitive linguistic correlates**
Actions (behaviour, language)	Smell, taste, touch, audition, vision	Perceived/produced language
Phyletic motor (primary motor cortex)	Phyletic sensory (primary sensory cortex)	Single semantic features (e.g. colour, shape, taste)
Acts	Polysensory	Integrated semantic features, basic level categories, prototypes
Programs	Episodic	Personal semantic frames
Rules, plans/Conceptual	Semantic/Conceptual	General semantic frames, superordinate categories, abstract processing

1.3.1 Semantic features

The term 'semantic features' in its traditional linguistic sense (Weinreich, 1966) has been used to describe properties varying in complexity from concrete, sensory-motor based (*banana*: +curved +yellow) to fairly abstract contextually-based (*bachelor*: +male +unmarried). The processing of basic sensory features such as size, colour, shape, movement pattern, sound, taste and smell, activates modality-specific semantic networks at the *phyletic sensory* level, which are then integrated at the *polysensory* level in order for events and objects in the environment to be perceived as a seamless whole (Fuster, 2009). A concrete subordinate level word such as *strawberry* refers to an object associated with rather specific, sensory-based features and feature constellations, making it likely to be associated with representations at these levels.

1.3.2 Semantic categories

Rosch, Mervis, Gray, Johnson & Boyes-Braem (1976) proposed that categorical semantic relations are hierarchically ordered, with superordinate (*food*), basic (*berry*) and subordinate (*strawberry*) terms. The cognitive categorization of entities and objects has been suggested to be based on certain essential features (Ungerer & Schmid, 2006). Sensory-motor based semantic features (e.g. colour, shape, smell) are shared to different degrees by words at different hierarchical levels. The higher the level, the less concrete a word is, e.g. *berry* is less concrete than *strawberry*, but their referents still share sensory features (e.g. 'small', 'sweet'). Berries can also be part of categories which are even more abstract and general, such as the superordinate terms *food* or *dessert*. A mental representation of *food* may or may not include basic sensory semantic features associated with *berry*. Members of the cognitive category *food* have the common denominator of 'edibility', but these edible things can have a wide variety of tastes, smells, textures, shapes and colours. The notion of 'prototype' (Rosch, 1978) can perhaps be related to categorization based on integrated semantic features.

In a recent study (Crutch & Warrington, 2008), subjects with left middle cerebral artery stroke aphasia were shown to have processing advantages for subordinate level words (e.g. *dalmatian*), in contrast to healthy controls who process basic level terms (e.g. *dog*) with greater ease, and semantic dementia patients who are better with superordinate terms (e.g. *animal*). The cause of semantic impairments in stroke aphasia and in semantic dementia have been suggested to differ, with aphasia leading to impairments of controlled access to semantic representations, whereas semantic representations themselves are degraded in semantic dementia (Jeffries & Lambon Ralph, 2006).

Superordinate and basic categories are more abstract in the sense that they may depend on activation of information in disparate areas of the brain, but they also lack the consistent linkage to sensory semantic features which is present in more subordinate words. Following the models of Fuster (2009) and Paivio (2007), the fact that the subordinate level term *dalmatian* is strongly associated with specific visual features, whereas the basic level term *dog* is not, could make subordinate terms easier to access when executive and linguistic processes are impaired but visual semantic processes are intact.

1.3.3 Semantic frames

Word representations may also be associated by linguistic and pragmatic context without sharing basic semantic features. For example, the word *strawberry*, in addition to being related to perceptually and functionally similar concepts such as *raspberry*, is also related to contextually cooccuring concepts which may be concrete (e.g. *cream*), as well as abstract (e.g. *summer*)[7]. A number of different theories describe contextually related information, using terms such as 'semantic frames' (Fillmore, 1985), 'scripts' (Schank & Abelson, 1977) and 'idealized cognitive models' (Lakoff, 1987). Despite certain differences, all these theories have in common that they assume word processing to be dependent on larger structures of encyclopaedic knowledge being activated (Geeraerts, 2010). Semantic frames may involve whole scenarios and situations, including concrete objects as well as events, actions and more abstract knowledge (Ungerer & Schmid, 2006). This paper does not aim to analyze the differences between these approaches. Instead, it will focus on their basic similarity, i.e. that they all emphasize the importance of background knowledge in word processing.

Comparisons of the importance of categorically vs. contextually related words for abstract and concrete word processing (Crutch & Warrington, 2005; Duñabeitia, Avilés, Afonso, Scheepers & Carreiras, 2009), suggest that categorical relationships are stronger for concrete words, whereas abstract words are more intimately related to contextually cooccuring words (i.e. words occurring in the same semantic frame).

Following the same general hierarchical model of information processing as above (i.e. Fig 1, Tab 1-2), more complex, semantic frame-based representations can be associated with information on different levels. Concrete, contextually related objects can be regarded as being related to features on the lowest phyletic sensory level just like concrete, categorically related objects, with the difference that an association from *jordgubbe* ('strawberry') to *grädde* ('cream') involves a connection within a *sensory-motor based frame* instead of just involving a sensory-based similarity such as associating *jordgubbe* ('strawberry') with *smultron* ('wild strawberry'). Thus, a context-based relation can be assumed to be cognitively more complex in general, i.e. a word with a meaning without overlapping perceptual features has to be accessed and selected from a number of possible contexts.

At the next, *episodic frame* level, autobiographical experiences are represented (Fuster, 2009). Although the complexity and richness of memory representations increase from phyletic sensory to episodic, these levels of representation share the property that they reflect things that can be directly perceived in the environment and experienced with the body. The more diversely distributed semantic networks corresponding to higher, conceptual levels are "formed to a large extent by the repeated coactivation and instantiation of similar, more concrete (e.g. episodic) memories" (Fuster, 2009, p. 2062), which are nested within the larger networks. The more abstract, conceptual levels above the episodic level, correspond to the level of *general semantic frames*. Superordinate categories which are not directly associated with sensory-motor semantic features are also placed on this level.

1.4 Empirical support for the proposed model: Word association experiment

In order to obtain experimental support for the proposed model of word meaning, word relations in the mental lexicon were investigated using a word association test. The effect of word abstractness/concreteness as well as neurophysiological

7 In Sweden, strawberries with cream are traditionally served at midsummer celebrations.

correlates of abstract/concrete word processing was investigated. This was done by comparing concrete and abstract noun processing in healthy speakers as well as speakers with aphasia due to anterior and posterior lesions. Word associations were assumed to be related to the different hierarchical levels of information processing in the brain summarized in Tab. 3. To the author's knowledge, this kind of analysis of word associations has not been performed previously. The free word association task makes it possible to shed some light on the question as to whether the assumed semantic feature representations and semantic frame representations have a mental reality. Results show that the semantic relations between cue words and the produced associations differ in healthy as compared to aphasic subjects.

Table 3: Types of possible relations between cue words and associations

Relation to cue word	**Definition**	**Example**
1. Sensory-motor based feature	Association related to a single basic sensory-motor based semantic feature of the cue word, e.g. colour, taste, shape.	*strawberry-red*
2. Sensory-motor based category	Association related to sensory-motor based semantic features of the cue word. The associated words belong to the same superordinate category.	*strawberry-raspberry* *strawberry-wild strawberry*
3. Sensory-motor based frame a) 'Body/External'-related context b) 'Body/Visceral'-related context	Association which has sensory-based semantic features which are not, however, shared with the cue word.	a) *strawberry-cream* b) *strawberry-hungry*
4. Personal frame	Association taken from a context which is episodic/autobiographical rather than representative for people in general. Includes associations to person names, episodic memories and evaluating comments.	*strawberry-grandmother* (if the person e.g. has a grandmother who loves strawberries) *strawberry-yesterday* (if the person had strawberries yesterday) *strawberry-nice*
5. General frame	Association occurring in the same general semantic frame as the cue word. The association is not based on clearly identifiable sensory-motor based semantic features.	*strawberry-summer* *strawberry-food*

1.4.1 Hypotheses

On the assumption that semantic features related to lower level semantic networks (phyletic sensory and polysensory), mostly dependent on posterior cortices, would be well-preserved in speakers with anterior lesions, it was hypothesized that associations involving shared semantic features would be more common in this group than in associations produced by speakers with posterior lesions, as well as speakers without aphasia. It was further hypothesized that speakers with anterior lesions would have difficulty in accessing higher-level, semantic frame-based information, both due to the lack of sensory information and due to the greater demands selecting a word from a semantic frame may put on executive functions. Conversely, since speakers with posterior lesions could be expected to have problems processing low-level visual features, it was hypothesized that associations involving higher-level (more abstract) words would more likely be produced by such speakers than by speakers with frontal lesions and speakers without brain damage.

2. Method

2.1 Participants

Twelve Swedish speakers (ten female) without communication problems in the age range of 23-79 years (*M*=47; *SD*=19) participated. Contact with four right-handed subjects with left-hemisphere lesions (three female), (Tab. 4) was established through the Neurology Department at Malmö University Hospital and the Aphasia Association in Malmö-Lund. They had all been treated at the Stroke Clinic at Malmö University Hospital and were diagnosed with aphasia using the standard tests. Three had anterior lesions and one had posterior lesions[8]. The healthy and aphasic subjects were approximately matched as regards their age and education levels and all subjects gave their informed consent to participate in the study.

Table 4: Aphasic participants with left hemisphere lesions

Participant	Age	Onset of aphasia	Diagnosis	Latest CT-scan	Localization of lesions
1 (female)	41	1989 04 25	Cerebral infarct	2000 08 22	Anterior (frontoparietal, mainly frontal)
2 (female)	66	2004 10 08	Cerebral infarct	2004 10 27	Anterior (frontoparietal, mainly frontal)
3 (female)	31	2007 02 12	Cerebral infarct	2007 10 30	Anterior (temporoparietal)
4 (male)	76	2004	Cerebral infarct	2004	Posterior (occipital)

2.2 Materials

30 nouns with high concreteness values[9] (M = 605, SD = 26) and imageability values[10] (M = 599, SD = 30) (Appendix 1), and 30 nouns with low concreteness values (M = 277, SD = 38) and imageability values (M = 379, SD = 77), were chosen from the Medical Research Council (MRC) Psycholinguistic Database (Coltheart, 1981). Familiarity values[11] did not differ significantly for abstract

8 The participant with posterior (occipital) lesions had reading difficulties and a right-sided homonymous hemianopia, meaning a lack of vision in the right visual field, but no other perceptual deficits. It should also be pointed out that posterior lesions are much rarer than anterior lesions, which accounts for the fact that only one person with occipital lesions participated in the present study.

9 Concreteness values are based on subjects' ratings of the degree of which words refer to concrete, physical objects.

10 Imageability values are based on subjects' ratings of how easily words evoke mental images.

11 Familiarity values are based on subjects' ratings of how familiar, i.e. frequently experienced, words are.

nouns $M = 526$, $SD = 38$ and concrete nouns $M = 503$, $SD = 56$, $t(58) = -1.872$, $p = 0.066$.

The words with high concreteness and imageability values are likely to be strongly related to the lower sensory-motor levels of processing, whereas the words with low concreteness and imageability values can be assumed to involve higher-level, more abstract conceptual processing. Concreteness, imageability, and familiarity values range from 100-700, with 100 being the least concrete/imageable/familiar and 700 the most concrete/imageable/familiar. The English nouns from the database were translated to Swedish using Lexin (2007).

The nouns used in the present study had 1-4 syllables ($M = 2.55$, $SD = 0.922$), to minimize the risk that word length could affect comprehension negatively for the aphasic participants. The mean number of syllables of concrete nouns ($M = 2.43$, $SD = 0.817$) and abstract nouns ($M = 2.67$, $SD = 0.922$) did not differ significantly $t(58) = -1.037$, $p = 0.304$.

Word frequencies from the Stockholm Umeå Corpus (SUC) (Ejerhed, Källgren, Wennstedt & Åström, 1992) were obtained for the Swedish translations of the nouns. Although the abstract nouns had a higher mean frequency $M = 58.93$, $SD = 76.368$ than the concrete nouns $M = 11.83$, $SD = 25.551$, $t(58) = -3.204$, $p < 0.01$, this difference was deemed unavoidable, due to the fact that SUC consists of written texts from newspapers and novels, where abstract words might be more common than in speech.

2.3 Procedure

In the word association test, participants were instructed to say the first word that the word uttered by the test leader made them think of, and they were informed that any answer would be correct as long as it was the first word that came to mind. Prior to the test, two practice words, *katt* ('cat') and *stol* ('chair'), were presented in order to verify that the participants had understood the instructions correctly. 30 concrete and 30 abstract nouns were then presented orally by the test leader. Every second noun presented was abstract. The same order of presentation was used for all participants. Pauses and repetitions of the nouns were made when necessary. The test was recorded with a Marantz PMD660 Portable Solid State Recorder and an IMG Stage Line ECM-302 B Boundary Microphone.

2.4 Data analysis: Coding of semantic relations

The five types of word associations previously listed in Tab. 3, corresponding to different levels of semantic networks (1-5), as well as categories for perseverations, derivations, absent and unidentifiable associations (6-9), were coded in the material. All labelling was discussed and agreed on by the author and the main and co-supervisors.

3. Results

3.1 Semantic relations between cue words and associated words

The data, coded according to the previously described labels, was analyzed in order to determine the extent of the different kinds of relations found between test words and associated words produced by the test participants. Some examples of associations are summarized in Tab. 5.

Table 5: Labelling of the relations between cue words and associations with examples from the data

Relation to cue word	**Definition**	**Example**
1. Sensory-motor based feature	Association related to a single basic sensory-motor based semantic feature of the cue word, e.g. colour, taste, shape.	*gurka-grön* 'cucumber'-'green' *choklad-sött* 'chocolate'-'sweet'
2. Sensory-motor based category	Association related to sensory-motor based semantic features of the cue word. The associated words belong to the same superordinate category.	*varg-räv* 'wolf'-'fox' *limousin-bil* limousine'-'car'
3. Sensory-motor based frame a) 'Body/External'-related context b) 'Body/Visceral'-related context	Association which has sensory-based semantic features, but which are not shared with the cue word.	a) *dragkedja-jacka* 'zipper'-'jacket' b) *makaron-hungrig* 'macaroni'-'hungry' *glädje-skratt* 'joy'-'laughter'
4. Personal frame	Association taken from a context which is episodic/autobiographical rather than representative for people in general. Includes associations to person names, episodic memories and evaluating comments.	*depression-meditation* *sköldpadda-tant* 'turtle'-'(old) lady' *fördel-logoped* 'advantage'-'speech therapist'
5. General frame	Association occurring in the same general semantic frame as the cue word. The association is not based on clearly identifiable sensory-motor based semantic features.	*säckpipa-Skottland* 'bagpipe'-'Scotland' *optimism-pessimism*
6. Perseveration	Repetition of a previously uttered word or word stem which is unrelated to the cue word	*samvete-osant* 'conscience'-'untrue' *kris-osant* 'crisis'-'untrue' *passion-opassion* 'passion'-'unpassion'
7. Derivation	Word based on the same stem as the cue word but involving a change of word class.	*glädje-glad* 'joy'-'joyful' *ärlighet-ärlig* 'honesty'-'honest'
8. Absent	The subject is unable to produce any association.	
9. Unknown	Association which could not be categorized as any of the types 1-6.	

In the healthy subjects, concrete cue words gave rise to a large number of sensory-motor based associations, most of which were categorically related based on sensory semantic features or belonged to a sensory-based semantic frame (54%). However, a large proportion of the associations produced as responses to concrete cue words by the healthy subjects were general semantic frame based (27%, the next largest category) (Tab. 6; Fig. 4). In the anterior aphasic group, sensory-motor based categorical and sensory-motor frame based associations constituted an even larger proportion of their associations (78%), whereas general semantic frame associations were fewer than in controls (only 12%). The subject with posterior lesions produced fewer sensory-motor based associations (17%), whereas the largest proportion (50%) of his associations were general semantic frame-based. It should also be noted that he was unable to produce associations for 23% of the concrete cue words, making his total number of analysable associations rather small.

As regards abstract cue words, they naturally never led to associations based on sensory-motor features or categories as defined in the present study[12] (Tab. 7, Fig. 4). Thus, for the abstract cue words, all associations were considered to be semantic frame-based. In the healthy participants, 83% of the associations for abstract cue words fell into the general semantic frame category. In the anterior aphasic group, a dramatically lower proportion of the associations (39%) were based on general semantic frames. Of the remaining associations to test words, many were personal frame associations (22%), perseverations (14%), or even absent (13%), patterns which did not occur for the concrete cue words in the anterior group and not for any words in the healthy subjects. The subject with occipital lesions, in a manner similar to the controls, produced mainly general semantic frame associations for abstract words (73%).

12 I.e., association words involving perceptually observable semantic features shared by the cue words.

Figure 4: Distribution of association types produced by control (group 1), anterior aphasic (group 2) and posterior aphasic (group 3) subjects. Associations for abstract words are shown at the top of the figure and associations for concrete words at the bottom figure.

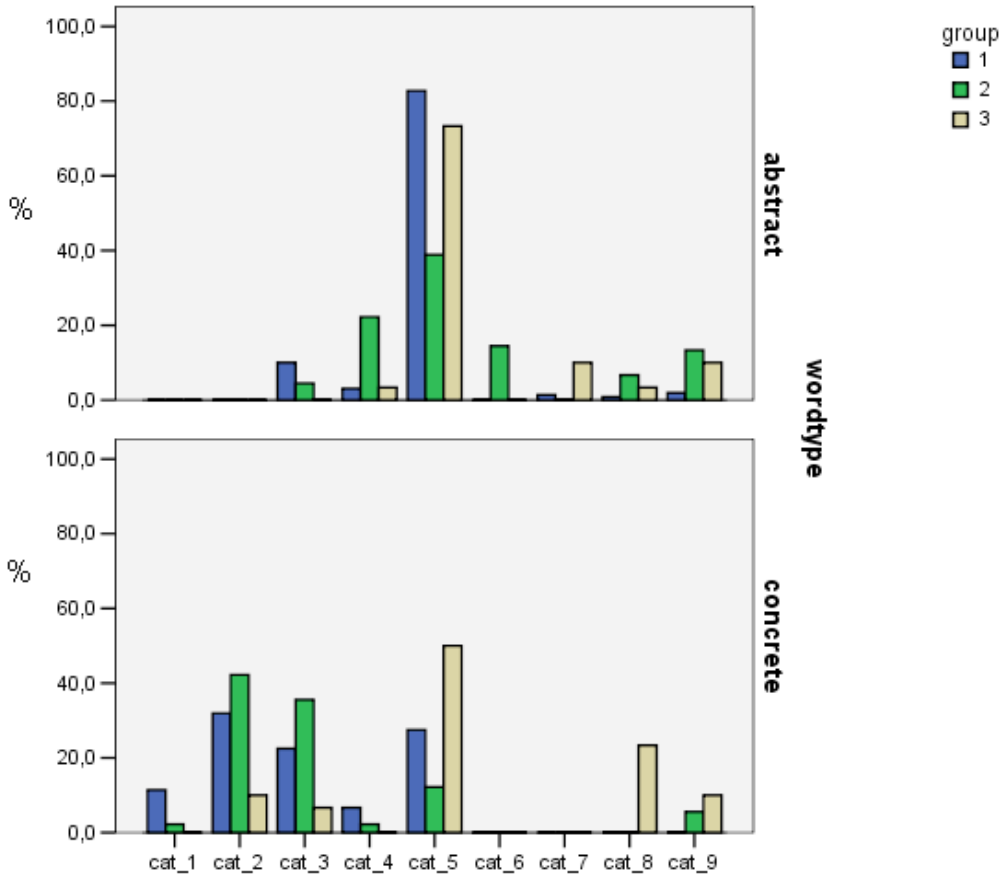


Table 6: Distribution of association types for concrete cue words produced by healthy, anterior aphasic, and posterior aphasic subjects

Nr	Category	Healthy (%)	Anterior aphasia (%)	Posterior aphasia (%)
1	Sensory-motor feature	11,4	2,2	0
2	Sensory-motor category	31,9	42,2	10,0
3	Sensory-motor frame	22,5	35,6	6,7
4	Personal frame	6,7	2,2	0
5	General frame	27,5	12,2	50,0
6	Perseveration	0	0	0
7	Derivation	0	0	0
8	Absent	0	0	23,3
9	Unknown	0	5,6	10,0

Table 7: Distribution of association types for abstract cue words produced by healthy, anterior aphasic, and posterior aphasic subjects

Nr	Category	Healthy (%)	Anterior aphasia (%)	Posterior aphasia (%)
1	Sensory-motor feature	0	0	0
2	Sensory-motor category	0	0	0
3	Sensory-motor frame	10,0	4,4	0
4	Personal frame	3,1	22,2	3,3
5	General frame	82,8	38,9	73,3
6	Perseveration	0	14,4	0
7	Derivation	1,4	1,1	10,0
8	Absent	0,8	5,6	3,3
9	Unknown	1,9	13,3	10,0

4. Discussion

4.1 Differences between groups

The results from the word association experiment revealed differences between the participant groups as regards the semantic relationships between cue words and associations. In the healthy subjects, a very large proportion of the associations given as response to abstract nouns, as well as a considerable part of the concrete word associations were words belonging to general semantic frames, i.e. which were not directly associated with any sensory-motor based features. In the anterior aphasic group, abstract nouns triggered repeated associations to words related to personal semantic frames, e.g. autobiographical experiences and personal characteristics, whereas concrete nouns mostly gave rise to sensory-based word associations, in particular concrete words sharing sensory-based semantic features with the cue words. The subject with posterior lesions showed the opposite pattern, with mainly general semantic frame-based word associations for abstract as well as concrete cue words and very few sensory/visual-based associations.

Repetition(s) of a previous word (perseveration), as well as absence of an association, were more common for the abstract nouns in the anterior aphasic group (Tab. 7, Fig. 4, Appendix 2d). The subject with posterior lesions, on the other hand, was unable to access words associated with a number of the concrete test nouns (Tab. 6, Fig. 4, Appendix 2c).

The results obtained support the idea that semantic features and semantic frames can be integrated in a general model of neurocognitive information processing proposed by Fuster (2009), which assumes a hierarchical organization of memory, with unimodal and polymodal sensory semantic networks at the bottom levels, episodic semantic networks at an intermediate level, followed by more abstract, conceptual levels of representation, which are less directly associated with sensory-motor features and with personal experiences.

4.2 Neural correlates of concrete word meaning

Since the posterior aphasic subject's lesions are localized to the occipital lobe, which is mainly involved in visual processing, his difficulties with concrete nouns can be thought to be caused by a failure to access semantic networks involving low-level visual feature representations. Word access from visual input, e.g. naming objects and colours from visual presentation, has previously been shown to be selectively disturbed in persons with aphasia due to left occipital lesions[13]. In the present study, occipital lesions were associated with specific problems accessing concrete nouns from verbal presentation, supporting the assumption that posterior areas involved in processing of visual information, e.g. colours and shapes, are intimately involved in the processing of concrete nouns, not only when they are activated by visually presented stimuli. This indicates that low-level semantic networks involved in the perception of concrete objects and entities are crucial for the processing of the concrete words denoting them, even in the absence of visual presentation or explicit mental imagery.

Thus, vision-related and other sensory representations are a likely contributing factor to the processing advantage normally present for concrete as compared to abstract nouns, as suggested by e.g. Paivio (2007) and Pulvermüller (1999). The involvement of perceptual semantic networks in posterior cortices also makes concrete noun processing likely to be relatively well preserved in aphasia caused by left anterior lesions. In the present study, this is manifest as the production of a larger proportion of sensory-based associations, in particular words denoting objects sharing sensory-based features with the cue word (Tab 6; Fig 4, for examples see Appendix 2c).

4.3 Neural correlates of abstract word meaning

The fact that aphasic subjects with anterior lesions were relatively more impaired in abstract word processing also supports the hypothesis that the distribution of neuronal activity in semantic networks is more anterior at higher, more abstract levels of processing. Accessing pragmatic and linguistic context (semantic frames) puts greater demands on executive and linguistic processes mediated by anterior brain areas. Although the test nouns elicited both categorical and contextual associations in both aphasic and control subjects, the pattern of consistently staying within an episodic memory context was only observed in the anterior aphasic group (Tab. 7, Fig. 4, Appendix 2d). The explanation for this may be that when access to general semantic frames is disturbed through anterior brain lesions, personal semantic frames are easier to access due to their perceptual and emotional salience. Another aspect of the repeated associations to the same autobiographical context is that it may be considered as a form of perseveration behaviour. It is possible that impairments in executive processing in the subjects with anterior lesions may have made the personal contexts difficult to inhibit once they were activated. Accessing semantic frame-based word associations, rather than perceptually similar concepts, puts greater demands on selecting the contextually appropriate information and keeping it in working memory while at the same time inhibiting irrelevant information. There is neurobiological support

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13 In addition to this, other visuo-verbal disturbances may also be present, such as alexia without agraphia (impaired reading without impaired writing).

for the idea that selection processes are mediated by anterior, e.g. prefrontal brain areas (Scheler, 1999).

4.4 Hierarchical categorical relationships and abstraction: General word association patterns in brain damaged speakers

The subjects with aphasia due to anterior lesions mainly produced categorically related words which were on the same, subordinate, visually detailed level as the concrete cue words, whereas the subject with aphasia resulting from a posterior lesion mainly produced categorically related associations which were on a lexically superordinate, more abstract conceptual level and were not related to any specific sensory-based semantic features. For example, several of the food items elicited the unspecific association *mat* ('food'), while the other participants' associations were words describing the type of food, its properties or other specifically associated concepts (Appendix 2e). Producing a superordinate instead of a basic level term as response to the subordinate level concrete cue words was very rare in any of the other participants.

This contrasting pattern between subjects with anterior and posterior stroke aphasia is similar to previous findings in subjects with stroke aphasia and semantic dementia (Crutch & Warrington, 2008), with posterior (occipital) lesions being associated with a pattern similar to that found in semantic dementia. Meaning representations dependent on an amodal semantic hub in the anterior temporal lobe have been suggested to be degraded in semantic dementia, leading to the loss of detailed semantic information, whereas executive impairments are the cause of semantic impairments in stroke aphasia (Jeffries & Lambon Ralph, 2006; Patterson, Nestor & Rogers, 2007). In the present study, differences were found between speakers with different types of stroke aphasia. Given the fact that the occipital lobe processes modality-specific (visual) information and that occipital lesions are unlikely to affect executive function, the semantic impairment in posterior aphasia may be a result of a failure to access modality-specific visual meaning representations.

4.5 Linguistic modelling of meaning

The present study is relevant for linguistic modelling of meaning, in particular the integration of different kinds of meaning representation in a general model of information processing assuming different levels of semantic networks. The results from the word association test are consistent with the assumption that different kinds of associated semantic networks are important for the processing of concrete as compared to abstract nouns – more specifically, sensory-based, e.g. visual semantic features for concrete nouns and general semantic frames for abstract nouns. The coordination of the more diverse meaning networks related to semantic frames is more dependent on executive functions. When access to higher more abstract, levels of representation is hampered by anterior lesions, word processing becomes more dependent on sensory-based information, reflected in the present study as retrieval of representations of perceptually similar objects when associating to concrete nouns. In the case of abstract words, which are not clearly associated with sensory experiences, personal semantic frames based on episodic memories, which are more concrete, are accessed when abstract nouns are given as input and general semantic frames are unavailable. Conversely, damage to visual cortex may leave conceptual levels of representation for abstract words well preserved, but cause problems accessing representations at the lower, sensory-based levels and thus impair concrete word access.

4.6 Future studies

The specific contexts for the abstract noun associations revolved around personal characteristics and experiences. Since a number of the abstract nouns have a positive or negative emotional valence, they may evoke emotional and autobiographical memories to a higher extent. Nevertheless, this type of association was also present for neutral abstract nouns (e.g. *reaktion-stroke* ('reaction'-'stroke'), *tendens-målmedveten* ('tendency'-'goal-oriented'), Appendix 2d, participant 3). Emotion-related words have been suggested to belong to a group that is neither truly abstract nor concrete, since they are perceived within (Wiemer-Hastings, Krug & Xu, 2001; Altarriba & Bauer, 2004) and they are likely to involve visual and motor representations of facial expressions as well as limbic structures such as the amygdala (Pulvermüller, 1999), brain regions which are not as affected by anterior lesions. In the present study, emotionality of the cue words was not controlled or systematically varied, and subcortical meaning networks which may be involved in processing of emotional words were not distinguished in the model. Therefore, in a follow-up study, it would be interesting to see if it is possible to extend the model to the processing of different types of abstract nouns (e.g. emotional-nonemotional).

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Appendix 1: Nouns

Appendix 1a: Concrete nouns with concreteness, imageability, and familiarity values.

English	Swedish	Syllables	Concreteness	Imageability	Familiarity
amplifier	förstärkare	4	564	559	474
bagpipe	säckpipa	3	601	594	397
butterfly	fjäril	2	593	624	481
camera	kamera	3	627	576	550
carnation	nejlika	3	625	611	490
cauliflower	blomkål	2	642	567	462
chocolate	choklad	2	576	611	560
clarinet	klarinett	3	633	593	464
cottage	stuga	2	593	607	543
crocodile	krokodil	3	583	601	456
cucumber	gurka	2	653	623	536
dress	klänning	2	595	595	588
emerald	smaragd	2	613	602	457
iron	järn	1	584	561	555
leopard	leopard	3	595	635	431
limousine	limousin	3	624	595	505
macaroni	makaron	3	631	608	498
milk	mjölk	1	670	638	588
oak	ek	1	588	590	515
peach	persika	3	617	613	536
revolver	revolver	3	592	629	486
silk	siden	2	538	510	482
strawberry	jordgubbe	3	610	631	539
thermometer	termometer	4	612	581	481
tortoise	sköldpadda	3	602	539	415
tweezers	pincett	2	590	619	415
window	fönster	2	609	602	621
volcano	vulkan	2	591	627	461
wolf	varg	1	595	610	537
zipper	dragkedja	3	599	632	556

Appendix 1b: Abstract nouns with concreteness, imageability, and familiarity values.

English	Swedish	Syllables	Concreteness	Imageability	Familiarity
advantage	fördel	2	282	292	562
anger	ilska	2	315	488	541
beginning	början	2	318	359	593
circumstance	omständighet	4	250	210	511
combination	kombination	4	326	326	493
conscience	samvete	3	255	386	536
crisis	kris	1	319	375	521
depression	depression	3	303	453	541
enthusiasm	entusiasm	4	266	464	506
exception	undantag	3	260	232	512
fear	rädsla	2	326	394	569
future	framtid	2	311	413	612
hatred	hat	1	239	417	544
honesty	ärlighet	3	278	386	578
hostility	fientlighet	4	277	437	472
ideal	ideal	3	253	331	521
insult	förolämpning	4	375	477	552
joy	glädje	2	300	533	545
loyalty	lojalitet	4	261	411	491
mood	humör	2	234	394	541
morale	moral	2	220	341	535
obedience	lydnad	2	238	394	500
optimism	optimism	3	240	418	500
passion	passion	2	300	467	502
prestige	prestige	2	248	394	441
reaction	reaktion	3	312	395	533
responsibility	ansvar	2	222	294	532
tendency	tendens	2	243	261	507
tradition	tradition	3	291	354	526
uncertainty	osäkerhet	4	237	283	451

Appendix 2: Word associations[14]

14 For anonymity reasons, associations consisting of person names are not specified in any of the following tables (2a-e). Further, words marked with * are novel constructions which do not exist in the Swedish lexicon, most frequently a semantically possible compound word.

2a: Word associations for the concrete nouns produced by healthy participants.

Concrete nouns	Participant F44 Control	Participant F58 Control	Participant F25 Control	Participant M78 Control
katt 'cat'	mjuk 'soft'	gosig 'cuddly'	hund 'dog'	lo 'lynx'
stol 'chair'	sitta 'sit'	bekväm 'comfortable'	bord 'table'	måne 'moon'
krokodil 'crocodile'	farlig 'dangerous'	farlig 'dangerous'	krokodiljägaren 'crocodile hunter'	varan 'monitor lizard'
pincett 'tweezers'	hårstrån 'hairs'	aj! 'ouch!'	tops 'cotton swab'	gripverktyg 'gripping tool'
klarinett 'clarinet'	musik 'music'	musik 'music'	instrument 'instrument'	klang 'timbre'
jordgubbe 'strawberry'	sommar 'summer'	sommar 'summer'	hallon 'raspberry'	smultron 'wild strawberry'
dragkedja 'zipper'	gylf 'fly'	varmt 'warm'	knapp 'button'	blixtlås 'zipper'
makaron 'macaroni'	NAMN (NAME)	hungrig 'hungry'	spaghetti 'spaghetti'	spaghetti 'spaghetti'
fönster 'window'	utsikt 'view'	glas 'glass'	dörr 'door'	dörrar 'doors'
sköldpadda 'tortoise'	tant 'old lady'	hård 'hard'	katt 'cat'	djur 'animal'
persika 'peach'	len 'smooth'	len 'smooth'	hallon 'raspberry'	plommon 'plum'
termometer 'thermometer'	värme 'heat'	kallt 'cold'	grader 'degrees'	barometer 'barometer'
stuga 'cottage'	mys 'cosy'	semester 'vacation'	hus 'house'	villa 'villa'
leopard 'leopard'	mönstrad 'patterned'	vig 'lithe'	kattdjur 'feline'	jaguar 'jaguar'
blomkål 'cauliflower'	gott 'nice'	grönsak 'vegetable'	grönsak 'vegetable'	grönkål 'borecole'
fjäril 'butterfly'	sommar 'summer'	sommar 'summer'	sommar 'summer'	dagslända 'mayfly'
klänning 'dress'	tyg 'cloth'	tant 'lady'	kjol 'skirt'	kjol 'skirt'
limousin 'limousine'	dyrt 'expensive'	bil 'car'	bil 'car'	bil 'car'
smaragd 'emerald'	grön 'green'	ring 'ring'	smycken 'jewelry'	diamant 'diamond'
mjölk 'milk'	kaffe 'coffee'	kossor 'cows'	mejeriprodukt 'dairy food'	vatten 'water'
siden 'silk'	lyxigt 'luxurious'	tyg 'cloth'	silke 'silk'	silke 'silk'
choklad 'chocolate'	sött 'sweet'	kakao 'cocoa'	godis 'candy'	kola 'toffee'
nejlika 'carnation'	blomma 'flower'	blomma 'flower'	blomma 'flower'	tulpan 'tulip'
revolver 'revolver'	krig 'war'	skjuta 'shoot'	vapen 'weapon'	pistol 'gun'
järn 'iron'	hårt 'hard'	blodvärde 'blood count'	material 'material'	koppar 'copper'
varg 'wolf'	otäck 'scary'	Rödluvan 'Little Red Riding Hood'	hund 'dog'	schäfer 'alsatian'
säckpipa 'bagpipe'	Skottland 'Scotland'	Irland 'Ireland'	Skottland 'Scotland'	blåsinstrument 'wind instrument'
gurka 'cucumber'	grön 'green'	Västerås 'Västerås' (Swedish pickle brand)	grön 'green'	tomat 'tomato'
förstärkare 'amplifier'	ljud 'sound'	högre 'louder'	gitarr 'guitar'	tratt 'funnel'
vulkan 'volcano'	Etna 'Etna'	Etna 'Etna'	bergart 'rock type'	Etna 'Etna'
ek 'oak'	träd 'tree'	träd 'tree'	träd 'tree'	bok 'beech'
kamera 'camera'	minnen 'memories'	foto 'photo'	fotografi 'photograph'	bildburk 'picturebox'

2b: Word associations for the abstract nouns produced by healthy participants.

Abstract nouns	**Participant F44 Control**	**Participant F58 Control**	**Participant F25 Control**	**Participant M78 Control**
glädje 'joy'	kärlek 'love'	barn 'children'	lycka 'joy'	sorg 'sorrow'
tradition 'tradition'	jul 'Christmas'	jul 'Christmas'	jul 'Christmas'	följd 'consequence'
början 'beginning'	dagen 'day'	start 'start'	slut 'end'	slutet 'end'
ilska 'anger'	oro 'unease'	arg 'angry'	raseri 'rage'	aggression 'aggression'
lojalitet 'loyalty'	trogen 'faithful'	godsint 'kindhearted'	mod 'courage'	gemenskapen 'fellowship'
undantag 'exception'	krig 'war'	alla 'all'	ibland 'sometimes'	regel 'rule'
depression 'depression'	jag 'me'	ledsen 'sad'	psykofarmaka 'psychopharmalogical drugs'	nedstämdhet 'blues'
moral 'morale'	etik 'ethics'	etisk 'ethic'	misstro 'distrust'	etik 'ethics'
reaktion 'reaction'	snabbt 'quick'	observant 'observant'	illdåd 'misdeed'	uppfattning 'comprehension'
hat 'hatred'	avsky 'disgust'	avsky 'disgust'	glädje 'joy'	agg 'grudge'
ärlighet 'honesty'	positivt 'positive'	trogen 'faithful'	trogen 'faithful'	ärlig 'honest'
fördel 'advantage'	bra 'good'	förmån 'benefit'	tårta 'cake'	nos 'nose'
osäkerhet 'uncertainty'	olustigt 'unpleasant'	tveksam 'doubtful'	blygsam 'modest'	vaghet 'vagueness'
samvete 'conscience'	rent 'clean'	---	tankar 'thoughts'	rent 'clean'
kris 'crisis'	oro 'worry'	katastrof 'disaster'	livskris 'crisis of life'	osäkerhet 'insecurity'
passion 'passion'	kärlek 'love'	förkärlek 'fondness'	kärlek 'love'	lycka 'joy'
förolämpning 'insult'	otrevlig 'unpleasant'	styggt 'naughty'	vett 'code of conduct'	motsägelse 'contradiction'
ideal 'ideal'	förebild 'role model'	förebild 'role model'	livsmål 'aim in life'	synpunkt 'viewpoint'
entusiasm 'enthusiasm'	iver 'keenness'	---	sprallig 'peppy'	ivrig 'keen'
lydnad 'obedience'	nödvändighet 'necessary'	respekt 'respect'	trofast 'faithful'	respekt 'respect'
kombination 'combination'	möjlighet 'possibility'	både 'both'	lås 'lock'	sammansättning 'composition'
humör 'mood'	glädje 'joy'	glad 'happy'	tankar 'thoughts'	ilska 'anger'
prestige 'prestige'	kämpa 'struggle'	---	vilja 'desire'	noggrann 'scrutinous'
omständighet 'circumstance'	situation 'situation'	besvärligt 'troublesome'	---	svårighet 'difficulty'
rädsla 'fear'	obehag 'unpleasantness''	oro 'worry'	olyckor 'accidents'	skraj 'harish'
ansvar 'responsibility'	makt 'power'	skyldighet 'onus'	plikt 'duty'	rädd 'careful'
framtid 'future'	tillförsikt 'reassurance'	snart 'soon'	nutid 'present'	ålderdom 'old age'
optimism 'optimism'	positivt 'positive'	glad 'happy'	pessimism 'pessimism'	glädje 'joy'
fientlighet 'hostility'	obehag 'unpleasantness'	agg 'grudge'	vänlighet 'kindness'	aggression 'aggression'
tendens 'tendency'	förmåga 'ability'	orsak 'cause'	tyckas 'seem'	tänker 'thinks'

2c: Word associations for the concrete nouns produced by aphasic participants.

Concrete nouns	**Participant 1 Anterior**	**Participant 2 Anterior**	**Participant 3 Anterior**	**Participant 4 Posterior**
katt 'cat'	mus 'mouse'	hund 'dog'	hund 'dog'	kvinna 'woman'
stol 'chair'	bord 'table'	bord 'table'	bord 'table'	sitta 'sit'
krokodil 'crocodile'	giraff 'giraffe'	fanta* 'elefant'	ödla 'lizard'	trädgård 'garden'
pincett 'tweezers'	finne 'pimple'	peang 'forceps'	ögonbryn 'eyebrow'	huvud 'head'
klarinett 'clarinet'	gitarr 'guitar'	trumpet 'trumpet'	spela 'play'	instrument 'instrument'
jordgubbe 'strawberry'	mjölk 'milk'	hallon 'raspberry'	hallon 'raspberry'	mat 'food'
dragkedja 'zipper'	knappar 'buttons'	dragsko '~grommet'	jacka 'jacket'	mage 'belly'
makaron 'macaroni'	pasta 'pasta'	---	pasta 'pasta'	efterrätt 'dessert'
fönster 'window'	dörr 'door'	karm 'frame'	putsa 'polish'	utsikt 'view'
sköldpadda 'tortoise'	bur 'cage'	våreld 'kalanchoe flower'	hav 'sea'	---
persika 'peach'	frukt 'fruit'	apelsin 'orange'	banan 'banana'	efterrätt 'dessert'
termometer 'thermometer'	Fahrenheit	feber 'fever'	kallt 'cold'	temperatur 'temperature'
stuga 'cottage'	hus 'house'	sommarnöje 'summer relaxation'	skog 'forest'	boning 'dwelling'
leopard 'leopard'	tiger 'tiger'	geopard[sic] 'cheetah'	savann 'savannah'	djur 'animal'
blomkål 'cauliflower'	broccoli 'broccoli'	rosenkål 'brussels sprout'	usch 'yuck'	mat 'food'
fjäril 'butterfly'	puppa 'pupa'	---	himmel 'sky'	fågel 'bird'
klänning 'dress'	kjol 'skirt'	kostym 'suit'	fashion	klädnad 'clothing'
limousin 'limousine'	taxi 'taxi'	bil 'car'	New York	---
smaragd 'emerald'	diamant 'diamond'	---	safir 'sapphire'	---
mjölk 'milk'	grädde 'cream'	smörgås 'sandwich'	laktolmjölk [sic] 'lactose-free milk'	dryck 'drink'
siden 'silk'	tyg 'fabric'	koppar 'copper'	Indien 'India'	plagg 'garment'
choklad 'chocolate'	godis 'candy'	kola 'toffee'	gott 'tasty'	mat 'food'
nejlika 'carnation'	blomma 'flower'	ros 'rose'	jul 'Christmas'	---
revolver 'revolver'	gevär 'rifle'	skott 'shot'	pistol 'pistol'	uppskjutningsredskap* '~launching device'
järn 'iron'	guld 'gold'	koppar 'copper'	rost 'rust'	---
varg 'wolf'	björn 'bear'	räv 'fox'	Norrland	---
säckpipa 'bagpipe'	instrument 'instrument'	klarinett 'clarinet'	Skottland 'Scotland'	blåsinstrument 'wind instrument'
gurka 'cucumber'	tomat 'tomato'	tomat 'tomato'	grön 'green'	mat 'food'
förstärkare 'amplifier'	högtalare 'loudspeaker'	radio 'radio'	högtalare 'loudspeaker'	höjare* '~increaser'
vulkan 'volcano'	vatten 'water'	berg 'mountain'	Etna	---
ek 'oak'	träd 'tree'	björk 'birch'	golv 'floor'	träd
kamera 'camera'	lins 'lens'	foto 'photo'	digital 'digital'	tar bilder 'takes pictures'

2d: Word associations for the abstract nouns produced by aphasic participants.

Abstract nouns	**Participant 1 Anterior**	**Participant 2 Anterior**	**Participant 3 Anterior**	**Participant 4 Posterior**
glädje 'joy'	surhet* '~grumpyness'	sorg 'sorrow'	glad 'happy'	sorg 'sorrow'
tradition 'tradition'	kontext 'context'	glädje 'joy'	stenbock 'capricorn'	sed 'custom'
början 'beginning'	the end	slut 'end'	slut 'end'	inledning 'introduction'
ilska 'anger'	arg 'angry'	---	arg 'angry'	arg 'angry'
lojalitet 'loyalty'	upprättelse 'redress'	---	jag 'me'	mycket lojal 'very loyal'
undantag 'exception'	expression	---	odd	bekräftelse 'confirmation'
depression 'depression'	meditation 'meditation'	fönster 'window'	MAS	sorglighet* '~sadness'
moral 'morale'	etik 'ethics'	tankeställare 'eye-opener'	Lund	gärningsåsikt*
reaktion 'reaction'	kontext 'context'	sant 'true'	stroke 'stroke'	reagera 'react'
hat 'hatred'	ilska 'anger'	ilska 'anger'	MAS	ilska 'anger'
ärlighet 'honesty'	människa 'person'	sant 'true'	lojal	varar längst 'lasts the longest'
fördel 'advantage'	jobb 'work'	sant 'true'	logoped 'speech therapist'	mitten 'the middle'
osäkerhet 'uncertainty'	skälvningar 'tremblings'	orädd 'unafraid'	feg 'cowardly'	jag 'me'
samvete 'conscience'	moral 'morale'	osant 'untrue'	vän 'friend'	förmåga 'ability'
kris 'crisis'	glädje 'joy'	osant 'untrue'	stress 'stress'	svårighet 'difficulty'
passion 'passion'	NAMN (NAME)	opassion* 'unpassion'	röd 'red'	önskan 'wish'
förolämpning 'insult'	mamma 'mother'	osant 'untrue'	mobba 'bully'	nedsågande*
ideal 'ideal'	NAMN (NAME)	sant 'true'	---	bästis '~best friend'
entusiasm 'enthusiasm'	together	---	NAMN (NAME)	entusiastisk 'enthusiastic'
lydnad 'obedience'	kris 'crisis'	olydnad 'disobedience'	hund 'dog'	eftergöra* '~do as someone says'
kombination 'combination'	arg och ledsen 'angry and sad'	---	dans 'dance'	samband 'relation'
humör 'mood'	ups and downs	ohumör*'unmood'	glad 'happy'	ilska 'anger'
prestige 'prestige'	inte bra 'not good'	---	bra jobb 'good work'	---
omständighet 'circumstance'	väljer 'chooses'	---	läkare 'doctor'	orsak 'cause'
rädsla 'fear'	glad 'happy'	orädd 'unafraid'	inte prata 'not to speak'	feghet 'cowardice'
ansvar 'responsibility'	föräldrarna 'the parents'	oansvarig 'irresponsible'	svara 'answer'	veta 'know'
framtid 'future'	purples?	orädd 'unafraid'	arbeta 'work'	imorgondag* '~tomorrowday'
optimism 'optimism'	glada människor 'happy people'	orädd 'unafraid'	jag 'me'	braåsikt* '~goodopinion'
fientlighet 'hostility'	mamma 'mother'	---	ovänner 'enemies'	ilska 'anger'
tendens 'tendency'	kulturen 'culture'	otendens* 'untendency'	målmedveten 'goal-oriented'	framåtskådande* '~forward looking'

2e: Word associations triggered by food-related nouns. Words without translation are the same in English as in Swedish. Associations produced by controls (A-L), anterior aphasic subjects (1-3) and the posterior aphasic subject (4).

	jordgubbe 'strawberry'	**makaron 'macaroni'**	**persika 'peach'**	**blomkål 'cauliflower'**	**mjölk 'milk'**	**choklad 'chocolate'**	**gurka 'cucumber'**
A	grädde 'cream'	spaghetti	nektarin 'nectarine'	soppa 'soup'	kall 'cold'	sött 'sweet'	svalt 'cool'
B	hallon 'raspberry'	spaghetti	hallon 'raspberry'	grönsak 'vegetable'	mejeriprodukt 'dairy product'	godis 'candy'	grön 'green'
C	hallon 'raspberry'	pasta	frukt 'fruit'	grönsak 'vegetable'	bomull 'cotton'	gott 'tasty'	gott 'tasty'
D	smultron 'wild strawberry'	spaghetti	plommon 'plum'	grönkål vegetable'	vatten 'water'	kola 'toffee'	tomat 'tomato'
E	bär 'berry'	pasta	frukt 'fruit'	grönsak 'vegetable'	grädde 'cream'	godis 'candy'	gott 'tasty'
F	äta 'eat'	pasta	luddig 'fuzzy'	huvud 'head'	kaffe 'coffee'	dryck 'drink'	grön 'green'
G	sommar 'summer'	pasta	sharonfrukt 'persimmon'	grönsak 'vegetable'	kor 'cows'	rättvisemärkt 'fair trade'	NAMN (NAME)
H	sommar 'summer'	NAMN (NAME)	len 'smooth'	gott 'tasty'	kaffe 'coffee'	sött 'sweet'	grön 'green'
I	god 'tasty'	god 'tasty'	mjuk 'soft'	stuvning 'stew'	vitt 'white'	mörkt 'dark'	vatten 'water'
J	sommar 'summer'	pasta	luden 'hairy'	nyttigt 'healthy'	ko 'cow'	kexchoklad 'chocolate wafer'	fräscht 'fresh'
K	sommar 'summer'	hungrig 'hungry'	len 'smooth'	grönsak 'vegetable'	kossor 'cows'	kakao 'cacao'	Västerås (Swedish pickle brand)
L	gott 'tasty'	barn 'child'	lent 'smooth'	gott 'tasty'	vitt 'white'	gott 'tasty'	tsatsiki
1	mjölk 'milk'	pasta	frukt 'fruit'	broccoli	grädde 'cream'	godis 'candy'	tomat 'tomato'
2	hallon 'raspberry'	---	apelsin 'orange'	rosenkål 'brussels sprout'	smörgås 'sandwich'	kola 'toffee'	tomat 'tomato'
3	hallon 'raspberry'	pasta	banan 'banana'	usch 'yuck'	laktolmjölk [sic] 'lactose-free milk'	gott 'tasty'	grön 'green'
4	mat 'food'	efterrätt 'dessert'	efterrätt 'dessert'	mat 'food'	dryck 'drink'	mat 'food'	mat 'food'

Appendix 3: Glossary

amygdala. Almond-shaped collection of nuclei located within the limbic system; plays a role in emotional and species-typical behaviours.

anterior. Located near or toward the front of the head.

aphasia. Inability to speak or comprehend language despite the presence of normal comprehension and intact vocal mechanisms.

cerebellum. Major structure of the hindbrain specialized for motor coordination.

cerebral cortex. Outer layer of brain-tissue surface composed of neurons (plural: cortices); the human cerebral cortex contains many folds.

[1]**cerebral infarct.** Coagulated blood seals off part of the blood supply, depriving an area supplied by the blood vessel of oxygen, causing cell death after a while

[1]**CT scan (Computed tomography scan).** X-ray based brain imaging method.

frontal lobe. Cerebral cortex anterior to the central sulcus and beneath the frontal bone of the skull.

hemisphere. Literally, half a sphere, referring to one side of the cerebellum or one side of the cerebral cortex.

inferior. Located below.

limbic system. Disparate forebrain structures lying between the neocortex and the brainstem that form a functional system controlling affective and motivated behaviours.

[1]**middle cerebral artery (cerebral medial artery).** The most important blood vessel supplying the brain from the point of view of language, spreads out around the lateral (Sylvian) fissure.

occipital lobe. Cerebral cortex at the back of the brain and beneath the occipital bone.

parietal lobe. Cerebral cortex posterior to the central sulcus and beneath the parietal bone at the top of the skull.

posterior. Located near or toward the back of the head.

[1]**posterior cerebral artery.** Blood vessel supplying posterior parts of the brain with blood.

prefrontal cortex. The cortex lying in front of the motor and premotor cortex of the frontal lobe.

Rolandic fissure (central fissure). Fissure which marks the boundary between the frontal and parietal lobe.

semantic dementia. Specific impairment of semantic memory in the context of well-preserved linguistic and other cognitive abilities, e.g. phonology, visual processing and decision-making (Jefferies & Lambon Ralph, 2006).

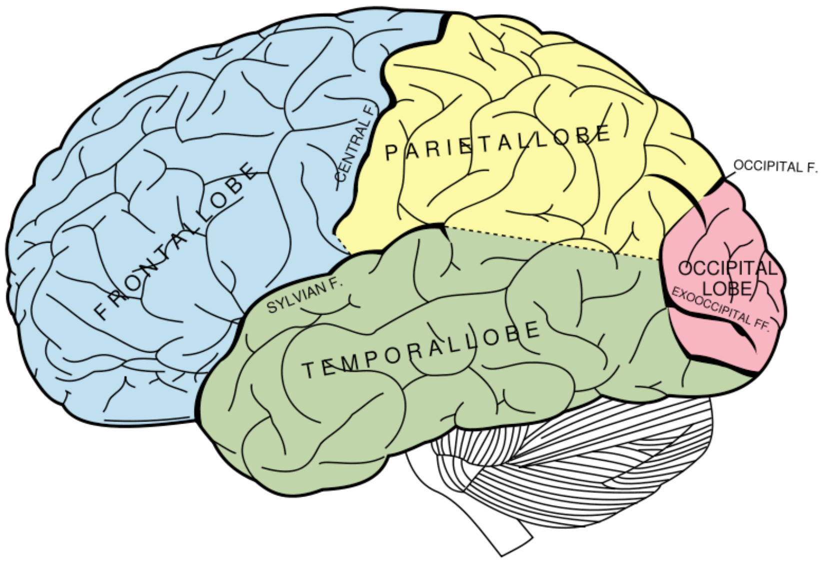
stroke. Sudden appearance of neurological symptoms as a result of severe interruption of blood flow.

temporal lobe. Cortex lying below the lateral fissure, beneath the temporal bone at the side of the skull.

Sources: (Kolb & Wishaw, 2006; [1]Ahlsén, 2006)

Appendix 4: Cortical areas

4a: Left frontal, parietal, temporal and occipital lobe (Wikimedia Commons, 2010). The temporal lobe contains the primary auditory cortex and visual association areas. The occipital lobe contains the primary visual cortex. The parietal lobe is involved, among other things, in the perception of touch and the processing of visuo-spatial information. The frontal lobe is involved in motor and executive functions (Kolb & Wishaw, 2006).



4b: Left hemisphere view of Broca's area (frontal) and Wernicke's area (temporoparietal) (Wikimedia Commons, 2010). These cortical areas, located around the Sylvian fissure, are traditionally viewed as 'language areas' due to the fact that brain lesions of these areas commonly results in language disturbances, e.g. aphasia (Kolb & Wishaw, 2006).