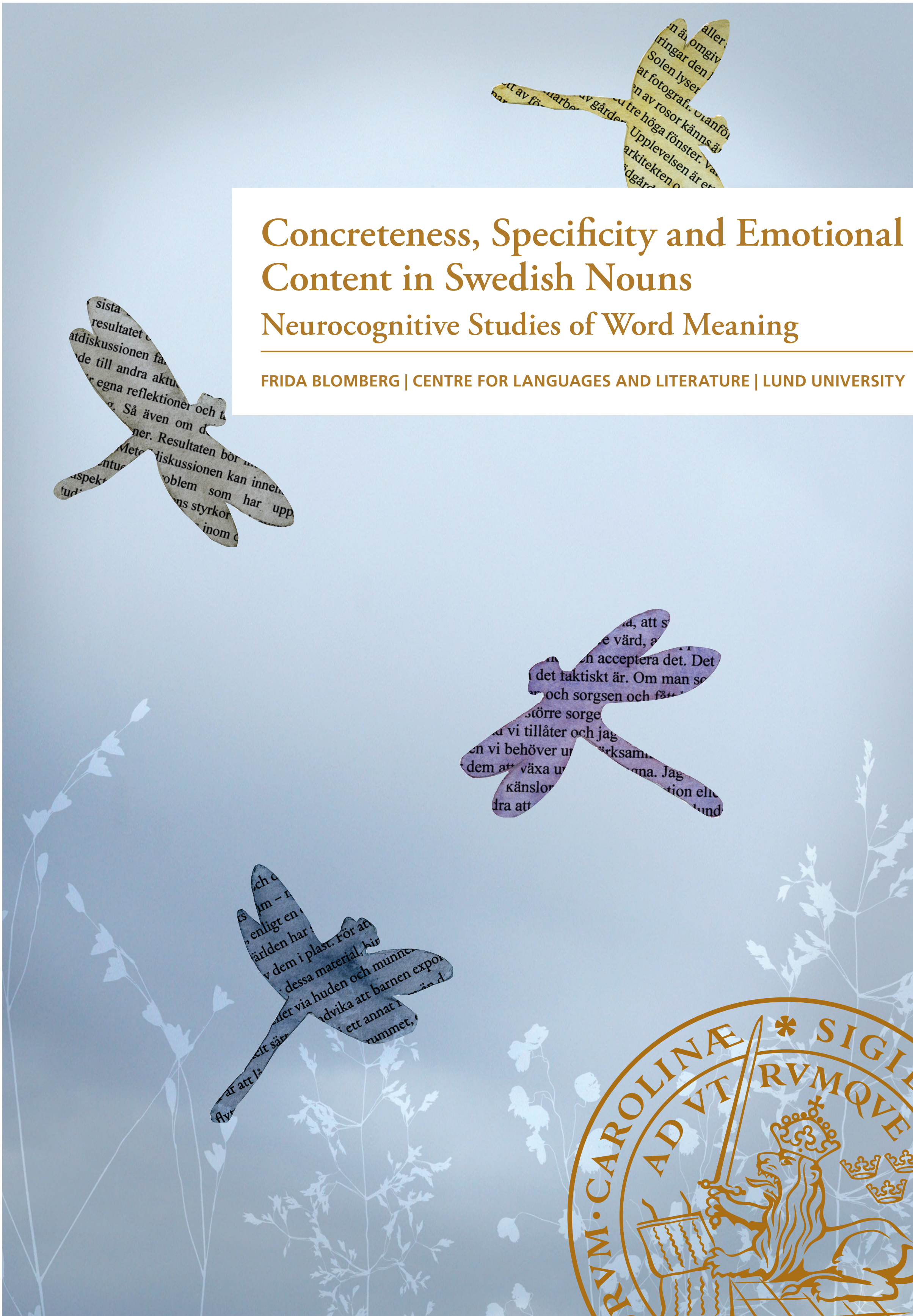


Concreteness, Specificity and Emotional Content in Swedish Nouns

Neurocognitive Studies of Word Meaning

FRIDA BLOMBERG | CENTRE FOR LANGUAGES AND LITERATURE | LUND UNIVERSITY

Concreteness, Specificity and Emotional Content in Swedish Nouns

Neurocognitive Studies of Word Meaning

Frida Blomberg

LUND UNIVERSITY

DOCTORAL DISSERTATION
by due permission of the Faculties of Humanities and Theology, Lund University, Sweden.

To be defended at LUX B152, Friday May 27, 2016 at 10.15-12.00

Faculty opponent

Professor Sebastian Crutch

Institute of Neurology, University College London

Organization

LUND UNIVERSITY

Centre for Languages and Literature

Author(s): Frida Blomberg

Document name

DOCTORAL DISSERTATION

Date of issue: May 27 2016

Sponsoring organization: Swedish Research Council

Title and subtitle: Concreteness, Specificity and Emotional Content in Swedish Nouns – Neurocognitive Studies of Word Meaning

Abstract: The present thesis investigated Swedish nouns differing in concreteness, specificity and emotional content using linguistic, psycholinguistic and neurolinguistic methods. The focus of Paper I was a semantic analysis of discourse produced by a person with a lesion in visual (left occipital) cortex. The results showed that the lesion site was related to with problems processing concrete nouns related to visual semantic features, as well as nouns with high semantic specificity. Paper II compared Swedish ratings of the cognitive psychological parameters imageability, age of acquisition and familiarity to English ratings, showing correlations indicating that ratings can be transferred between the two languages. Suggestions for constructing a Swedish psycholinguistic database were also outlined. In Paper III, four noun categories differing in specificity and emotional arousal (SPECIFIC, GENERAL, EMOTIONAL, ABSTRACT) were compared using a dichotic listening paradigm and a concrete/abstract categorisation task. EMOTIONAL nouns were shown to be processed faster than the other noun categories when presented in the left ear, possibly indicating more right hemisphere involvement. In Paper IV, PSEUDOWORDS as well as SPECIFIC, GENERAL, EMOTIONAL and ABSTRACT nouns were compared during lexical decision and imageability rating tasks using electroencephalography (EEG), targeting the event-related potentials (ERPs) N400 and N700, previously shown to be modulated by concreteness. On the assumption that abstract nouns have a larger number of lexical associates than more concrete nouns, N400 amplitudes were predicted to be smaller for abstract nouns than for concrete nouns. This prediction was supported by the results. Notably, even SPECIFIC and GENERAL nouns were observed to elicit different N400 amplitudes, in accordance with their hierarchical relationship in lexical semantic models. Bringing together theories and methods from linguistics, cognitive psychology and neuroscience, the present interdisciplinary thesis provides insights into word semantics as regards differences related to the cognitive dimension of concreteness and its relation to sensory and emotional meaning features.

Key words: Abstract, concrete, nouns, semantics, specificity, emotion, imageability, anomia, word ratings, EEG, ERP, N400, N700, dichotic listening, hemispheric lateralisation, lexical decision, Swedish, neurolinguistics

Classification system and/or index terms (if any)

Supplementary bibliographical information

Language: English

ISSN and key title

ISBN: 978-91-87833-75-5

Recipient's notes

Number of pages 187

Price

Security classification

Signature Frida Blomberg Date 2016-03-30

Concreteness, Specificity and Emotional Content in Swedish Nouns

Neurocognitive Studies of Word Meaning

Frida Blomberg

LUND UNIVERSITY

Cover art by Maj Persson, www.majpersson.se

The Faculties of Humanities and Theology
Centre for Languages and Literature
ISBN 978-91-87833-75-5 (print)
ISBN 978-91-87833-76-2 (pdf)

Printed in Sweden by Media-Tryck, Lund University
Lund 2016

Till min älskade dotter Mirja

Contents

Acknowledgements

No matter what you do, the people you meet in the process will invariably be as important, if not more, for making it worthwhile than the actual enterprises themselves. Quite a few people came into my life during the years that have passed since I moved into my office on the fifth floor of the Centre for Languages and Literature.

First of all, I would like to express my sincere gratitude to my supervisors at the Department of Linguistics: Merle Horne, who has been my main supervisor and Mikael Roll, who co-supervised. Thank you both so much for giving me the confidence to apply for the doctoral programme, for all the hours you spent on discussion and guidance, and for never ceasing to believe that this thesis would eventually be finished, despite me having serious doubts at times. Merle's enthusiasm for bringing different fields of research together has been a true inspiration and crucial for making this interdisciplinary work possible. Mikael's skills with everything experiment-related have been extremely helpful. I am also truly grateful to my third supervisor Magnus Lindgren at the Psychology Department, who provided a much needed bird's-eye view and who consistently pointed me towards the red threads of this work at times when I found myself deep inside the labyrinth.

Thank you Roger Johansson for being an excellent opponent at my pre-defense seminar, providing me with detailed suggestions for improvement of an earlier draft of this thesis.

I am very grateful to speech therapist Pia Apt, who has given me tons of great advice for working with aphasic participants and kindly helped me recruit participants for Paper I. Jonas Brännström helped me with the auditory setup and shared his knowledge about the dichotic listening method used in Paper III, thank you Jonas! I also want to thank Carl Öberg, who in addition to being a brilliant person and a dear friend, used his programming skills to make the data collection and database construction for Paper II possible. Joost van de Weijer has helped me a tremendous amount with e-prime programming and statistics advice throughout the writing of this thesis, thank you so much Joost! Thanks Johan Frid for helping me get access to word frequencies and for making neat figures out of WordNet data. Without the contributions of all of you this thesis would certainly not have been written!

I want to thank Marianne Lind and Hanne Gram Simonsen, who inspired me in my work with word ratings (Paper II) and gave me ideas for possible future projects.

I am also extremely grateful for having had access to the Humanities Lab, where the studies reported in Papers III and IV were carried out, and for the people there, in particular Annika Andersson, who showed great pedagogical skill in teaching me how to use the EEG system, and Stefan Lindgren and Henrik Garde who helped me solve a lot of technical issues along the way. Thanks Anna Hed for assisting with data collection for Paper IV! I would like to thank Susanna Björverud, Johan Dahl and Edin Kuckovic for always being helpful with computer-related problems.

Although one shouldn't judge a book based on its cover, thank you Maj and Anna Persson for making the book look pretty on the outside!

During my final year, the neurolinguistics lab group consisting of Merle and Mikael with all of their master and PhD students emerged. Pelle Söderström, Andrea Schremm, Anna Smålander, Anna Hed, Mikael Novén, Otto Ewald and Sabine Gosselke-Berthelsen: It has been great fun and extremely helpful to spend every other Monday morning with you guys, even on the occasions when the main focus of our communication was the exchange of pseudowords.

I am very grateful to all colleagues and good friends at the linguistics department who have contributed to fruitful discussions as well as making it enjoyable to go to work. I would like to especially thank Felix Ahlner, Mats Andrén, Sabine Gosselke-Berthelsen, Sandra Debreslioska, Victoria Johansson, Sara Lenninger, Simone Löhndorf, Susan Sayehli, Malin Svensson and Vi Thanh Son. Thanks Sandra, Maria and Victoria for pep talk/therapy sessions during the final writing hours. A big thank you also to my dear friends Emelie Stiernströmer, Andreas Lind, Maria Eggeling, Katarina Pernryd, Anna Svensson and Wanda Jakobsen. Special thanks to Liselotte Lindahl and Karl for being such fun playmates!

All of the people who have participated in my studies over the years also deserve to be mentioned, although they have to remain anonymous. You made this possible, thank you all so much!

I am deeply grateful to my mother and father Ingegerd and Kent Mårtensson for encouraging my interest in language in various ways since birth, and for always being there for me. Without all your help with everything from moving house several times, to regular daycare pickups and babysitting, I seriously doubt I would have gotten to this point! Thank you also to my brother Henrik Mårtensson and my father-in-law Börje Blomberg for always being ready to lend a helping hand.

Following the conventional form for this kind of text, I have saved the ones deserving the biggest thank you for last. In addition to resulting in this book, my years as a PhD student also happened to bring me my family. Johan and Mirja. You have both been extremely patient during my work with this thesis, especially in the final stages when I was very preoccupied with *tänkarmössorna* 'the thinking hats' as well as writing – or well – "Mom, you're not working! You're just sitting by your computer". I can't express how much I look forward to enjoying the upcoming days with you, present in mind as well as body.

List of original papers

Paper I

Mårtensson, F., Roll, M., Lindgren, M., Apt, P. & Horne, M. (2014). Sensory-specific anomic aphasia following left occipital lesions: Data from free oral descriptions of concrete word meanings. *Neurocase*, 20, 192-207.[1]

Paper II

Blomberg, F. & Öberg, C. (2015). Swedish and English word ratings of imageability, familiarity and age of acquisition are highly correlated. *Journal of Nordic Linguistics* 38(3), 351–364.[2]

Paper III

Blomberg, F., Roll, M., Lindgren, M., Brännström, J. & Horne, M. (2015). Emotional arousal and lexical specificity modulate response times differently depending on ear of presentation in a dichotic listening task. *Mental Lexicon* 10(2), 221–246.[3]

Paper IV

Blomberg, F., Roll, M., Lindgren, M., & Horne, M. (manuscript). Lexical specificity, imageability and emotional arousal modulate the N400 and the N700 during imageability rating and lexical decision tasks.

---

[1] Open access.

[2] Reprinted with permission from Cambridge University Press.

[3] Reprinted with permission from John Benjamins Publishing Company.

Abbreviations

AoA	Age of acquisition
CA	Context availability
CAT	Context availability theory
EEG	Electroencephalography
ERP	Event-related potential
fMRI	functional Magnetic Resonance Imaging
IR	Imageability ratings
LD	Lexical decision
LH	Left hemisphere
LPC	Late Posterior Complex, positive late ERP wave
MEG	Magnetoencephalography
N400	Negative ERP wave peaking at 400 ms post stimulus onset
N700	Negative ERP wave peaking at 700 ms post stimulus onset
RT	Response time
RH	Right hemisphere
SD	Semantic dementia
TMS	Transcranial magnetic stimulation

Introduction

According to common definitions (both in everyday life and in research contexts), concrete nouns are words with referents that can be experienced with the five senses, whereas abstract nouns do not directly refer to such visible and tangible referents. However, these broad categories can be expected to include a large variety of words, varying along sensory as well as emotional dimensions.

For example, two words likely to be categorised as concrete, but differing in lexical specificity (e.g. the word *squirrel* in relation to the word *animal*) might be associated with salient sensory features in terms of colours, shapes, sounds and smells to different degrees, making them differ in how easily one can imagine them visually. The use of more specific and more general nouns in discourse also differs, with general nouns being used to refer back to more specific referents: *I planted a peony. It's a really beautiful flower.*

A similar albeit not equivalent difference can be seen in abstract nouns like *happiness* and *theory*. They are both likely to be conceived of as being abstract because of their lack of physical referents, but might vary substantially in the degree to which they are associated with emotional experiences. Sensory and emotional perceptions are both bodily experiences, which could make abstract words with emotional content more concrete than emotionally neutral abstract words.

Scope of the thesis

The present thesis aims to shed more light on the semantic structure and neurocognitive processing of nouns which, broadly speaking, have meanings differing in their degree of concreteness. The investigation focuses on differences in noun concreteness related to sensory information, lexical specificity and emotional content. In order to address questions concerning the role of sensory and emotional information in word perception and production, a cross-disciplinary approach is taken, building on methods and models from several disciplines, including linguistics, psychology and cognitive science. The dichotomy of concrete and abstract words often assumed in cognitive psychological research is related to linguistic modelling of lexical semantic noun hierarchies and semantic structure in terms of semantic features. Throughout the thesis, the lexical semantic properties under investigation are empirically studied and discussed in relation to their possible neural correlates.

Four empirical studies were carried out, employing methods ranging from semantic analysis of content words in semi-spontaneous discourse and subjective ratings of word meaning properties, to psycho- and neurolinguistic experiments involving response time measurements, dichotic listening technique and recordings of brain activity using electroencephalography (EEG). These methods were combined in order to gain further knowledge about the linguistic and neurocognitive processing of word types differing in their concrete/abstract semantic content.

A study of noun processing in a person with lesions in visual brain areas (Paper I) investigated the hypothesis that this lesion localisation would selectively affect comprehension and production of vision-related words. Subsequent studies targeted the role of the left and right hemisphere in processing words differing in lexical specificity and emotional arousal (Paper III) and neurophysiological responses to words differing along the same dimensions (Paper IV).

The studies were all conducted on Swedish, a language where empirical investigations of the processing of concrete and abstract nouns has not previously been carried out. This resulted in a methodological study comparing English and Swedish ratings of word properties (Paper II). In addition to aiming at developing linguistic modeling of lexical structure, the present thesis thus also adds one more language to the previous body of research on concrete/abstract words.

Outline of the thesis

In Section 1, theoretical background regarding words' semantic difference as regards their degree of abstractness/concreteness is outlined, bringing together literature from the field of linguistics and other related disciplines. It ends with a summary of research questions addressed in the thesis. Section 2 briefly describes and motivates the methods used in the studies. In Section 3, the main results from each individual paper (I-IV) are discussed in more detail. The principal findings and conclusions are summarised in Section 4. Finally, in Section 5, suggestions for further studies are made.

1. Theoretical background

1.1 The concrete-abstract distinction

1.1.1 Concrete and abstract word meanings

Although abstract and concrete word meanings have been discussed in previous linguistic research (Ullmann, 1962; Lyons, 1977; Lakoff & Johnson, 1980; Schmid, 2000), there are no comprehensive linguistic models elaborating on the difference between concrete nouns such as *elephant* and abstract nouns such as *heritage*. In order to investigate the semantic processing of these word categories, the starting point has to be a clear idea what is meant by "concrete" and "abstract". The work included in the present thesis took its departure from the definitions previously used in a large body of research comparing concrete and abstract words, mainly in the fields of psychology and cognitive science. In this line of research, the concrete/abstract word categories have been operationalised as words that are high/low in subjective ratings on Likert-type scales of either 'concreteness' or the closely related cognitive psychological variable 'imageability', measuring the degree to which words are associated with sensory experiences.[4] This way of quantifying concrete/abstract has been used since the 1960's (Paivio, Yuille, & Madigan, 1968; Paivio, Yuille, & Rogers, 1969) and imageability and concreteness are only two of many psychological variables quantified in similar ways. In contrast, within the field of linguistics, concrete/abstract distinctions based on such quantitative measures have not been commonly used.

Another difference between linguistic and cognitive psychological modelling of concrete and abstract word meanings is that the latter has a long tradition of relating semantic processing of these word categories to assumed neurocognitive activity. With some exceptions (Fortescue, 2010; Mårtensson, Roll, Apt, & Horne, 2011), modelling word meaning using a neurolinguistic approach has not been a major focus for linguistic semantics.

[4] Word ratings of these and other variables are further described in Section 2.1.1.

The perhaps most common use of the terms 'abstract' and 'concrete' in linguistic theoretical work is to be found in models proposed by e.g. Lakoff & Johnson (1980) and Langacker (1990). In these very influential accounts, abstract meanings are seen as being grounded in embodied experience, i.e. in the perceptual systems of the human body and its sensory-motor interactions. Thus, knowledge belonging to abstract domains is grounded in basic domains, so that for example theories are conceptualised as buildings (e.g. "*construct a strong* argument", "*foundation* for your theory) or war ("*defend* a thesis") (Lakoff & Johnson, 1980). The meanings of expressions such as "the prices are rising" are grounded in the physical movement associated with situations such as "the balloon is rising" (Langacker, 1990). The idea of abstract concepts as grounded in perceptual experience is also advocated by Barsalou (1999, 2005), who argues that abstract word meanings can ultimately only be understood by means of concrete word meanings. This line of reasoning often presupposes a link between abstract and concrete words, where concrete words are more primary. This is not necessary for a concrete-abstract division based on whether words are directly associated with sensory semantic information or not.

Looking at abstract words from a different view-point, certain types of abstract nouns (so-called "shell nouns") have been analysed linguistically based on their function as "conceptual shells" in discourse (Schmid, 2000). Briefly described, shell nouns are nouns like *fact*, *idea* or *thing*, whose meaning is often specified in surrounding clauses (see 1.1.4 for further description) The idea that abstract word meanings have a greater need to be determined contextually than concrete meanings has parallels in psychological literature emphasising the importance of context for abstract words (Schwanenflugel, Harnishfeger, & Stowe, 1988).

For concrete words in particular, models of lexical semantic structure have been developed. These focus on hierarchical relations between words such as hyponymy, hyperonymy and partonomy (Miller & Fellbaum, 1991). In such hierarchical lexical semantic structures, words at more general levels such as *animal* can be seen as more abstract due to their having fewer defining features, in comparison to gradually more specific levels such as *bird* or *robin*. There have been fewer attempts to model the semantic structure of abstract words in similar ways, since they do not seem to be organised in the same type of hierarchical semantic structures.

Finally, emotional word meanings have also posed a challenge for lexical semantics. One way emotional meanings have been handled in linguistics is by assuming that words have 'connotations' and 'denotations' (e.g. Jackson, 2013; Ullmann, 1962). In this view, denotations, the dictionary-like definions of words, are regarded as constituting word meaning, whereas connotations are rather seen as subjective emotional experiences associated with words. Emotional word meanings, in a manner similar to other abstract word meanings, have also been analysed as being grounded in concrete domains such as colour or space (Lakoff & Johnson, 1980). In cognitive psychological research, emotional content is often quantified along the dimensions of 'valence' or 'arousal' and can be related to distinct patterns of performance in behavioural and neurocognitive experiments (Altarriba & Bauer, 2004; Citron, 2012; Kousta, Vigliocco, Vinson, Andrews, & Del Campo, 2011).

In order to bring together models of word semantics in linguistics and related disciplines such as cognitive psychology, which have large overlaps in their research interests, but at the same time differences in their theoretical and methodological approaches, the present thesis takes an interdisciplinary perspective. It aims to develop the linguistic modelling of nouns differing in concreteness, with a particular focus on nouns' specificity and emotionality. Models taking into account hierarchical lexical semantic structures (Miller & Fellbaum, 1991; Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976), semantic features (e.g. Weinreich, 1972) and abstract words' relation to context (Schmid, 2000; Schwanenflugel & Shoben, 1983) are related to cognitive psychological measures such as word imageability and emotional arousal. The interdisciplinary approach also makes it possible to relate meaning differences between word categories to possible differences in neurocognitive processing.

1.1.2 Concrete and abstract words and the brain

Neurocognitive differences in concrete and abstract word processing

The left hemisphere is language-dominant, i.e. generally more involved in the processing of linguistic information as compared to the right hemisphere. This hemispheric specialisation is evident in patients with language disturbances due to brain damage, where lesions to certain left-hemisphere brain regions are well-known to cause aphasia, whereas right hemisphere lesions typically do not.

In neuropsychological studies, dissociations of concrete and abstract word impairment have been found in patients with brain lesions. Most often, abstract words are affected more in neurological patients (Goodglass, Hyde, & Blumstein, 1969) but there are also cases showing the opposite pattern (Breedin, Saffran, & Coslett, 1994; Reilly, Grossman, & McCawley, 2006; Warrington & Shallice, 1984). A large number of psycho- and neurolinguistic studies with healthy participants also have revealed behavioural differences as well as different neural activation for concrete and abstract words. Concrete words have been seen to generally be processed faster and more accurately and be better remembered than abstract words (Kroll & Merves, 1986). Influential models aiming to explain this difference have proposed that concrete words have richer semantic representations involving sensory information (cf. Paivio, 1990; 2010), and alternatively, that abstract words are more difficult to process without contextual support (Schwanenflugel et al., 1988).

Differences in brain activity for concrete and abstract words have been shown using neuroimaging methods such as e.g. functional Magnetic Resonance Imaging (fMRI) (Binder, Westbury, McKiernan, Possing, & Medler, 2005; Sabsevitz, Medler, Seidenberg, & Binder, 2005). A metaanalysis of results from imaging studies (Wang, Conder, Blitzer, & Shinkareva, 2010) found that abstract words were associated with greater activity in the left inferior frontal gyrus and middle temporal gyrus, whereas concrete words were associated with stronger activation of the posterior cingulate gyrus, precuneus, fusiform gyrus, and parahippocampal gyrus in the left hemisphere. This has been interpreted as evidence for assuming more exclusively "verbal" processing for abstract concepts and more perceptual processing for concrete concepts, consistent with Paivio's (1990) 'dual coding theory' suggesting that abstract words depend on verbal representations, whereas concrete word meanings also involve a non-verbal system (e.g. sensory experiences). Originally, the dual coding theory assumed that verbal and non-verbal processing would be associated with the left and right hemisphere, respectively. Testing this hypothesis has, however, yielded mixed results. Section 1.4 contains some further discussion of hemispheric lateralisation of the processing of word categories differing in their semantic content.

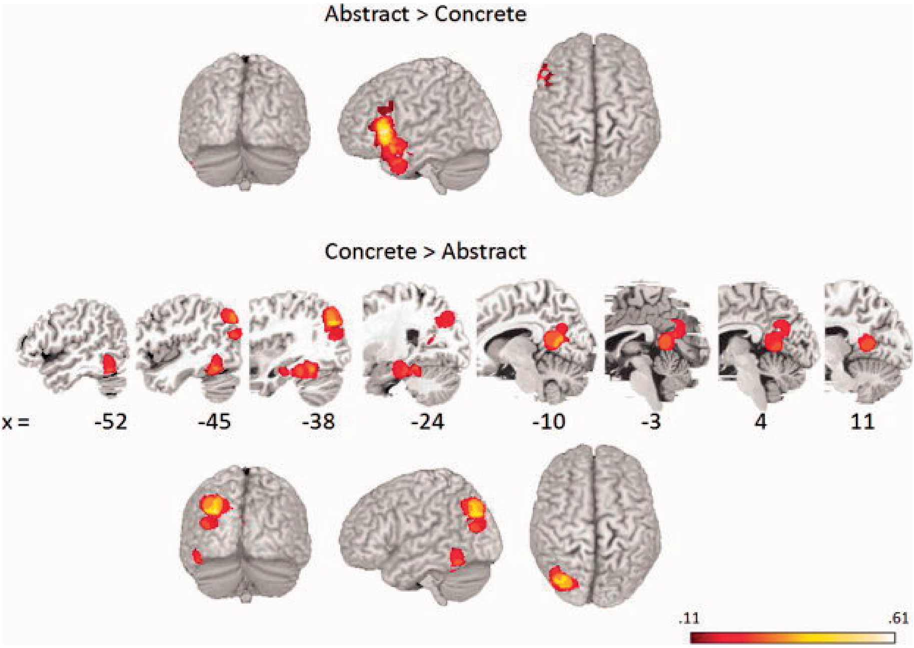


Figure 1
Differences in brain activation for concrete and abstract words (Wang et al., 2010), reprinted with permission from John Wiley and Sons. Copyright © 2010 Wiley-Liss, Inc.

Abstract and concrete words have also been seen to be associated with different electrophysiological patterns. Studies comparing abstract and concrete word processing using event-related potentials (ERPs) have shown differences in the 'N400' and 'N700' components, with concrete words giving rise to larger amplitudes in both time-windows (Barber, Otten, Kousta, & Vigliocco, 2013; Gullick, Mitra, & Coch, 2013; Huang, Lee, & Federmeier, 2010; Welcome, Paivio, McRae, & Joanisse, 2011; West & Holcomb, 2000). The N400 effect has been suggested to reflect greater activation of sensory features in long term memory for concrete words or alternatively, contextual integration (Kutas & Federmeier, 2011; Lau, Phillips, & Poeppel, 2008), whereas the N700 effect has been proposed to be related to tasks involving mental imagery (Gullick et al., 2013; West & Holcomb, 2000). The ERP method and concreteness-related ERP components will be further described in section 2.2.3.

Taken together, the above summarised results point towards a close relation between concrete words and sensory processing, whereas abstract words might involve a closer relation to linguistic processing. The view that words differ in the degree to which they are associated with sensory processing can be contrasted with theoretical accounts that do not take embodiment into account (Fodor, 1983) or which consider cognitive processing to be amodal (Pylyshyn, 1980) and it is further not considered to explain differences between concrete and abstract words in models that assume different degrees of dependence on verbal and situational contexts for concrete and abstract words (Schwanenflugel et al., 1988). Furthermore, the notions of sensory/imagery and verbal/linguistic information, unless further specified, could incorporate many different levels of processing. Regarding the "verbal system" Paivio (1978) p. 42 stated that:

> I will leave it to linguists and psycholinguists to propose what the nature of the verbal or linguistic representational system is like. For my purposes it is sufficient to suggest that the units of the verbal system are arbitrarily related to perceptual information.

The verbal information in Paivio's view can thus consist of morphemes, words, phrases or sentences. One assumption made by Paivio is that both concrete and abstract words are processed by the verbal system, but that concrete words are associated with additional sensory information processed by the non-verbal system, for example mental images (Paivio, 2010). The notion of verbal processing has, however, also been related to e.g. phonological processing (Binder et al., 2005), morphological structure (Reilly & Kean, 2007; Reilly, Westbury, Kean, & Peelle, 2012) and could also be interpreted as linguistic information in terms of sentence contexts.

1.1.3 Concrete words

Somatotopic representation of sensory and motor related words

If sensory information is activated during the processing of words with sensory-related meanings, specific predictions can be made regarding the brain activity elicited by words strongly associated with vision, hearing, touch, smell, taste. A framework which has generated numerous studies (Pulvermüller, 1999) builds on the assumption that words belonging to different sensory modalities are acquired in the context of the sensory experience of their referents. This leads to the formation of neuronal networks ("cell assemblies" in the terms of Pulvermüller (1999)). Perceiving the acquired word form automatically sparks off patterns of neural activation in brain areas associated with the sensory modalities which were active during word learning. This has been shown for example for motor verbs such as *kick* (Hauk, Johnsrude, & Pulvermüller, 2004) concrete nouns such as *table* (Pulvermüller, Preissl, Lutzenberger, & Birbaumer, 1996) and even for taste/smell-related words such as *cinnamon* (González, Barros-Loscertales, & Pulvermüller, 2006). One of the most well-known studies used event-related fMRI to compare the motor verbs *kick*, *pick* and *lick*, showing that these three words were each associated with activity in specific areas of the motor cortex (leg, finger and tongue, respectively) (Hauk et al., 2004).

Similar patterns have been found in studies of patients with lesions affecting different sensory and motor brain areas. Damage to modality-specific visual (occipital and occipitotemporal) cortex affects naming from visual input (most frequently pictures), as compared to naming from other sensory modalities or from actions (Gainotti, 2004). This condition is known as optic aphasia (Manning, 2000) or visuo-verbal disconnection syndrome (Luzzatti, Rumiati, & Ghirardi, 1998). At least two cases have also been reported where naming from verbal definitions rich in visual information was worse than naming from abstract or functional definitions (Forde, Francis, Riddoch, & Humphreys, 1997; Manning, 2000). Also supporting the idea that modality-specific brain areas are involved in processing of words with meanings strongly involving a certain modality, Parkinson's disease has been seen to selectively disturb the processing of motor verbs when patients are off medication (Boulenger et al., 2008) and damage to primary auditory cortex selectively impairs processing of sound-related concepts (Trumpp, Kliese, Hoenig, Haarmeier, & Kiefer, 2013).

Mental imagery

Mental imagery has been suggested to play an important role in concrete word representation (Paivio, 1990; Paivio et al., 1968; Rosch et al., 1976; West & Holcomb, 2000). Kosslyn, Ganis & Thompson (2001), p. 635 introduce mental imagery and its relation to perception as follows:

> Mental imagery occurs when perceptual information is accessed from memory, giving rise to the experience of 'seeing with the mind's eye', 'hearing with the mind's ear'. By contrast, perception occurs when information is registered directly from the senses.

Thus, mental imagery is a subjective phenomenon which is difficult to capture in any straightforward way. It is also complex in the way that many different neurocognitive processes are likely to be involved. In addition to the fact that imageability ratings may be more likely to capture visual imagery than imagery belonging to other sensory modalities, different types of mental imagery can be expected to be involved depending on the semantic information associated with the word. For example, shape and colour vs. location in space are processed by different neural pathways: the ventral and dorsal pathway, respectively. Fig. 2 shows the ventral pathway going from the occipital lobe to the inferior temporal lobe, and the dorsal pathway, going from the occipital lobe to the posterior parietal lobe. These pathways may thus contribute differently to processing aspects of imagery involving shape/colour or spatial information (Blazhenkova & Kozhevnikov, 2009; Kosslyn et al., 2001) and this can also be expected to affect semantic processing for words differing with respect to their spatial or shape/colour characteristics. In the studies carried out within the present thesis, focus was mainly on the semantic processing of concrete nouns referring to animals, objects, food, plants and tools, likely to involve meaning features more related to shape and colour than to locations in space (see Appendices of Papers I-IV).

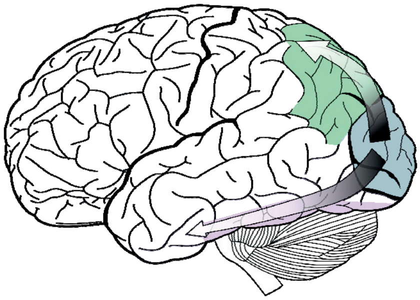


Figure 2
The ventral (purple) and dorsal (green) visual streams originating in the occipital lobe (grey). Figure from Wikimedia Commons, reprinted under the terms of the GNU free reproduction license.

Linguistic modeling of word meanings based on semantic features

The distributed nature of sensory semantic representations and processing in the brain can be related to compositional models of lexical semantics. According to structual and formal linguistic accounts (Lyons, 1977; Weinreich, 1972), word meanings can be decomposed into 'semantic features'. Semantic features in this sense can be described as word properties, which can be more or less abstract, defining the meaning of a word. For example, relatively abstract properties of the word *bachelor* such as [+human], [+adult], [+male], [+unmarried] (Saeed, 2009) would all count as features in the same way that [+edible], [+green] [+long] and [+watery] all are features of a *cucumber*. Thus, semantic feature analyses in this traditional sense do not differentiate between features differing in their degree of concreteness. However, viewing the concept of 'semantic feature' in light of neural organisation and studies showing that concrete nouns and verbs activate sensory and motor cortices (e.g. (Pulvermüller, 1999)), features can be related to specific sensory modalities and even subtypes of processing within them (e.g. vision, colour, shape) can be distinguished.

With respect to neurolinguistic modeling of word meaning, a proposal is made in Fortescue (2009; 2010). In this model, meaning components of words related to sensory and motor features were identified and schematically presented with hypotheses about the localisation of these meaning components to certain brain areas.

Another proposal for relating linguistic models of word meaning to models of neurocognitive processing is presented in Mårtensson, Roll, Apt & Horne (2011). Based on a hierarchical model of perception- and action-related semantics at different levels of abstractness (Fuster, 2009) it was proposed that semantic features processed in primary sensory and motor cortex are crucial for concrete word processing, whereas abstract words are more dependent on larger cognitive structures in line with those described as 'semantic frames' (Fillmore, 1985), 'idealised cognitive models' (Lakoff 1987) or 'scripts' (Shank & Abelson, 1977), involving higher-level processing in frontal brain regions. This connection of concrete words and sensory semantic features and abstract words with more complex, frame-like structures was supported by patterns in word associations produced by healthy and aphasic participants.

Words related to modality-specific sensory information

Regarding the relation of words with sensory semantic content, Viberg (1983) has proposed an implicational hierarchy of perception verbs *see* > *hear* > *touch* > *taste*, *smell*, further elaborated in Viberg (2015). This hierarchy was suggested based on cross-linguistic studies showing that vision-related basic perception verbs (e.g. *see*) seem to be nearly universal, and that vision-related verbs are more likely to be the basis for extending meanings to other domains (e.g. *I see* for *I understand*). Following up on this idea, San Roque et al. (2015) investigated perception words in thirteen languages belonging to nine different language families. They found that vision-related words were predominant in all languages, whereas variation between languages was found as regards the frequency with which words related to the other senses were used. A universal predominance of describing events using words with visual meaning components would be expected given the biological specialisation of vision in humans, with large areas of the brain being involved in vision and our high visual acuity. Thus, they found support for universal constraints in terms of the importance of vision-related expressions, whereas cultural-specific influences may also have an impact on the importance of other sensory features in meaning representations of different languages.

Concrete and abstract words in semantic dementia

As summarised in the above sections, there is evidence from neurological patients that sensory-related word meaning components are processed in modality-specific brain regions (such as primary motor, visual and auditory cortex). Moreover, there is evidence from another neurological condition, semantic dementia (SD) which is also relevant for understanding differences in concrete-abstract word processing. SD has been found to lead to semantic impairments which may be, at least on the surface, similar to those seen in patients with occipital/occipitotemporal lesions. That is, detailed sensory features related to words might be inaccessable, leaving only general superordinate words intact (Patterson, Nestor, & Rogers, 2007). Reversed concreteness effects (i.e. impairment of concrete words with preserved abstract vocabulary) was originally thought to be the most common pattern in semantic dementia, and has been seen in several case studies (Breedin et al., 1994; Papagno, Capasso, & Miceli, 2009; Reilly et al., 2006). However, the opposite has also been found in other patient studies (Jefferies, Patterson, Jones, & Lambon Ralph, 2009) and has been further supported by the results of transcranial magnetic stimulation (TMS) studies (Pobric, Ralph, & Jefferies, 2009). This might be explained by the fact that SD is commonly a result of degradation of the anterior temporal lobes, thought to function as a semantic hub, integrating semantic information distributed over modality-specific cortices (Patterson et al., 2007). The reversed concreteness effects seen in SD patients might be explained by assuming that these patients' lesions are localised to subregions of the anterior temporal lobes which are more involved in visual object recognition (Jefferies et al., 2009).

1.1.4 Abstract words

Semantic and feature-based analyses of abstract word meanings

Abstract words constitute the least homogenous category of words investigated in the present thesis, and arguably the most difficult to get a grip on (no pun intended!). Kemmerer (2014) also notes this and gives two examples of attempts to distinguish more fine-grained categories among the words traditionally lumped together as being abstract: Words related to numbers and emotions. He then reviews some studies indicating that both of these word categories might be grounded in different kinds of experiential information, i.e. emotional experiences and situations in which emotions occur, and counting on the fingers. Emotional words will be discussed more thoroughly in section 1.3.

A few additional studies have acknowledged the problem of abstract words being a negatively defined category, addressing the question of how abstract words' meaning structures might be cognitively organised. For example, steps towards more fine-grained analyses of the semantic structures underlying abstract words have been taken by means of asking subjects to rate their properties (Wiemer-Hastings & Xu, 2005) or features (Crutch, Troche, Reilly, & Ridgway, 2013). Wiemer-Hastings & Xu (2005) asked participants to provide properties for stimulus words differing in concreteness, with the hypothesis that concrete words would be more related to what they call entity properties ("sensory-related information"), whereas situation properties ("contextual information") and introspective properties ("emotional information") would be more important for abstract words, a hypothesis which they found support for in their data. In a similar vein, but using a more unrestricted task than feature ratings, Barsalou & Wiemer-Hastings (2005) analysed the information produced in free word descriptions. They contrasted abstract (*truth*, *freedom* and *invention*) and concrete (*bird*, *car* and *sofa*) words. They found that the information provided in the descriptions differed, with concrete word descriptions focusing more on objects, locations and behaviours, whereas abstract word descriptions were more centered around social interaction and mental states. However, these different types of information were present to some degree for all word categories, also indicating similarities.

Also focusing on the properties associated with abstract words, Crutch et al. (2013) related abstract conceptual feature ratings along the dimensions social interaction, morality, executive function, emotion, quantity, time, space, and polarity to patient data. Based on the feature ratings, made on 1-7 point scales (Crutch, Williams, Ridgway, & Borgenicht, 2012), words were plotted in a multidimensional semantic space using Latent Semantic Analysis (LSA). Further relating this data to neuropsychological testing, a patient with global aphasia was seen to have greater difficulties in spoken-written word matching tasks for words that were closer in semantic space.

A common denominator of these three studies is that they emphasise the importance of investigating the properties associated with abstract words themselves, not only abstract words' association with contextual information (which has been more extensively investigated and will be also be discussed here in the following paragraphs).

Abstract words and context

A number of theoretical accounts emphasise abstract words' dependence on a supporting context. One influential account, the 'context availability theory' (CAT) (Schwanenflugel et al., 1988; Schwanenflugel & Shoben, 1983), maintains that the differences seen in speed, accuracy and memory performance for concrete and abstract words can be explained by different degrees of contextual support associated with these word types. In particular, CAT suggests that it is more difficult to think of a context[5] for abstract words compared to concrete words, making abstract words harder to process in isolation. Similar to imageability and concreteness, the ease with which a context comes to mind can also be operationalised as a variable ('context availability' (CA)), measured on a 1-7 point scale where low scores = very difficult to come to think of a context, and high scores = very easy to come to think of a context. Schwanenflugel & Harnishfeger (1988) found that when CA was controlled for, the processing advantage of concrete stimuli disappeared. In the same study, they also measured reading time for abstract and concrete sentences embedded in paragraphs, with the result that reading time for abstract sentences was equal to that of concrete sentences, which they also interpreted as support for the context availability theory. An opposite prediction has also been made concering the relationship of context and concreteness; it has been proposed that the contextual constraints are greater for concrete than abstract words, i.e. that they occur in a more limited set of contexts

[5] In this case a situational context, e.g. "the World Series" for *baseball*.

because of their more specific semantic content (Wiemer-Hastings, Krug, & Xu, 2001).

Further developing the idea of different contexts or "cognitive frameworks" consisting of contextually related information, Crutch and colleagues (Crutch & Warrington, 2005; Crutch, Connell, & Warrington, 2009) suggested that whereas concrete words are organised in similarity-based frameworks based on shared semantic features and categorical relations, abstract words are organised in associative frameworks. In this view, the concrete word *apple* is assumed to be more strongly related to words belonging to the same semantic category, such as *pear*, *banana* etc. than to contextually related words (e.g. *tree*, *pie*). Abstract words such as *idea*, on the other hand, are taken to be less strongly associated with categorically related words such as synonyms (e.g. *thought*, *belief*), but more strongly related to words likely to appear in the same context (e.g. *idea – think*, *bright*). Crutch & Warrington (2005) found support for this idea looking at the performance of patients with refractory access deficits, a neurological condition where word processing is disturbed by previous presentation of closely related words. Hoffman (2015) further elaborates on the idea of associative and similarity-based frameworks, noting that the difference might be amplified by the co-occurence patterns of words as well as their physical referents. For example, fruits are often present together with other fruits and they have similar, yet distinct meanings and thus they cannot replace each other, whereas categorically related abstract words (often synonyms) are similar enough so that it is possible to choose one from a set of possible candidates in order to express a certain meaning. Looking at co-occurrences in the British National Corpus (BNC), Hoffman (2015) found support for this idea. Abstract words were more likely to co-occur with associated words, whereas concrete words were more likely to co-occur with categorically related words.

What kind of context?

The studies summarized in the previous paragraph all point towards a greater role of contextually related information for abstract than concrete words. However, it can also be observed that the notion of "context" is quite broad, and that different types of contexts are under investigation in different studies. As Hoffman (2015) notes, it may often be difficult to draw a sharp line between linguistic contexts or other types of contexts, especially using words as stimuli. Schwanenflugel et al. (1988) states that: "This contextual information may come either from the comprehender's prior knowledge or from the stimulus environment", p 500. Context is further described as "relevant world knowledge" linked to the words, i.e. real-world situations in which the words and their referents occur, and in the instructions for CA ratings, examples such as *baseball* – "the World Series" and *emotion* – "falling in love" are given. In another study by Schwanenflugel & Shoben (1983), the context consisted of written paragraphs in which the concrete and abstract stimuli were embedded. Crutch & Warrington (2005) used a task where written word stimuli were matched with targets from sets of other written words, and discussed their results in light of other studies

(Breedin et al., 1994; Schwanenflugel & Shoben, 1983) arguing for the importance of sentence contexts for abstract word acquisition. Westbury et al. (2013) based their definition of context on a co-occurrence model, where words are assumed to share the same contexts if they occur together with similar words in large corpora. Mårtensson et al. (2011) propose that abstract words are more dependent on cognitive structures such as 'semantic frames' (Fillmore, 1976), thought to involve encyclopaedic knowledge of real-world situations related to the word. The notion of semantic frame has, however, as discussed by Bednarek (2005), been used in many different senses. These include linguistic contexts, real-world knowledge, pragmatic functions, as well as sometimes being used as an umbrella term covering different kinds of contextual information.

Shell nouns

Schmid (2000) proposes a term under which a variety of abstract nouns can be incorporated: 'shell nouns'. The category comprises nouns such as *fact*, *problem*, *idea*, *plan*, *motivation*, *solution*, *aim*. Abstractness, in the sense of not referring to something that can be seen or touched, is a prerequisite for a noun to have the capacity to be a shell noun. It is, however, a functionally defined category, i.e., the characterisation of a noun as a shell noun is based on its use in context rather than on any inherent lexical properties. Shell nouns are "used to create conceptual shells for complex and elaborate chunks of information" (p 6). The complex information which the shell noun stands for is usually "unpacked" in surrounding clauses, e.g. "the eventual *aim* is to set up a new discipline from a fusion of two or more old ones" (p. 36). Shell nouns are described as having more unspecific/context-dependent meanings than "full-content" nouns (e.g. *teacher*, *cat*, *journey*), but less unspecific/context-dependent meanings than pronouns with anaphoric functions (e.g. *she*, *it*, *this*, *that*). Similar noun categories have been distinguished in other analyses using different labels, e.g. 'carrier nouns' (Ivanič, 1991), 'container nouns' (Vendler, 1968), 'low-content nouns' (Bolinger, 1977) and 'general nouns' (Haliday & Hasan, 1976) (for an overview, see (Schmid, 2000)). Shell nouns have been seen to be extensively used to create cohesion in academic texts (Aktas & Cortes, 2008) and they contribute to a text being perceived as being abstract (Schmid, 2000).

Relating the notion of shell nouns to the above discussion about linguistic context, nouns that have the capacity to function as shell nouns are often used in a way in which their meaning is specified in a linguistic context near the noun, frequently in a subordinate clause. Based on a distinction originally made by Lyons (1977) into first-order, second-order and third-order entities, Schmid (2000) distinguishes three levels of shell nouns. The shell nouns corresponding to the most abstract level (e.g. *concept*, *fact*, *issue*, *principle*, *problem*, *thing*, *message* and *rumour*) are suggested to be 'prime' shell nouns. At an intermediate level, there are 'good' shell nouns such as *belief*, *assumption*, *plan*, *likelyhood*, *certainty* and *permission*, which are replaceable by their "morphologically related verbs and adjectives", p. 86. The least prototypical level, 'peripheral' shell nouns represent events rather than abstract relations, including examples such as *move*, *measure*, *reaction*, *situation*, *procedure*, *time*, *place* and *area*.

Neurocognitive correlates of abstract words

As described synoptically in 1.1.2, abstract words have been associated with neural processing other than that assumed for concrete words. As found in the metaanalysis by Wang et al. (2010), in neuroimaging studies, abstract words have most consistently yielded greater activation in the left inferior frontal gyrus and middle temporal gyrus, areas involved in different aspects of verbal processing (although not exclusively, the left inferior frontal gyrus is also involved in e.g. response inhibition (Swick, Ashley, & Turken, 2008). In contrast, concrete words were more associated with activity in brain regions linked to sensory perception. This is in line with accounts such as the dual coding theory (Paivio, 1990), proposing that abstract words are mainly processed in a verbal system, whereas concrete words additionally involve processing in a nonverbal (sensory) system. Greater activation in the left inferior frontal gyrus is also known to be related to factors such as lower word frequency, task difficulty and working memory maintainance, but controlling for these factors, the association of abstract word processing and left inferior frontal gyrus activation seems to remain (Shallice & Cooper, 2013). As Shallice & Cooper (2013) maintain, the left inferior frontal gyrus might be either the locus of abstract word meaning representations, or involved in processes necessary for construction/retrieval of abstract word representations. In the latter case, the greater activation of the left inferior frontal gyrus for abstract words might reflect coordination of more widely distributed representations or inhibition of irrelevant associations.

1.2 Generality and specificity

1.2.1 Lexical specificity in relation to concreteness

An aspect of importance for understanding the notion of word concreteness that is a main focus of the present thesis is degree of semantic specificity. As outlined above, a great amount of research has focused on comparisons of abstract and concrete words. In parallel, there are lines of research more exclusively focusing on hierarchical semantic structures. These two viewpoints are, however, rarely brought together under the umbrella terms of abstractness-concreteness. Nevertheless, as will be discussed in the upcoming sections, the degree of semantic specificity and the degree of word concreteness share some important characteristics and may be associated with similarities in their neural and cognitive processing.

Among the few sources discussing the relation of concreteness and specificity, Ullmann (1962, p. 119) notes the following:

> The generic nature of our words has often been described as an element of *'abstractness'* in language. There is some danger of ambigiuity here since the usual opposition between abstract and concrete does not correspond to that between generic and particular. A word may be extremely general in meaning and yet remain on the concrete plane; thus, the terms *animal* and *plant* are the widest in range in the whole system of zoological and botanical classification, and yet they are concrete in the sense that specific animals and plants are tangible, material things as opposed to pure abstractions such as *liberty* or *immortality*. In a wider sense, however, generic terms can be regarded as 'abstract', i.e. more schematic, poorer in distinguishing marks than particular terms; as the logician would say, they have a greater extension and lesser intension: they apply for a wider range of items but tell us less about them. The word *tree*, for example, is more general and therefore more abstract than *beech*; in the same way, *plant* is more abstract than *tree* [...].

This description by Ullmann (1962) captures the fact that concrete nouns such as *animal* and *plant* are seldomly considered to be abstract, while at the same time their generality should make them more abstract relative to their more specific subcategories. Lyons (1977, p. 298) uses the label 'general nouns' to refer to different nouns such as *person*, *animal*, *fish*, *bird*, *insect*, *thing*, *place*, *stuff*, *material*, *quality*, *property* and *state*. The relation between concreteness and specificity is also addressed in Schmid's (2000) analysis of shell nouns, where he states that the notions of abstractness and unspecificity are both "essential semantic prerequisites for the successful use of shell nouns" (p. 9). He further mentions another similar functional analysis proposed by Haliday & Hasan (1976), where the term 'general nouns' is used, comprising a set of nouns (e.g. *people*, *person*, *creature, thing, object, stuff*) which they analyse mainly regarding their capacity to create cohesion in texts. These nouns are similar to the GENERAL noun category distinguished in papers included in the present thesis as well as the third-order shell nouns proposed by Schmid (2000). However, Haliday & Hasan's (1976) general nouns also include words such as *affair*, *matter*, *question* and *idea.* This shows differences as well as parallels between general superordinate level words such as *animal* and words more prototypically categorised as abstract such as *fact*. The present thesis follows up on these intuitions by taking specificity as well as concreteness into account in the design of empirical studies. Speakers' conscious categorisation of general nouns, in relation to abstract and specific/concrete nouns is compared with measures of neural processing for the different noun categories.

1.2.2 Modeling hierarchical lexical semantic structures

Hierarchical noun structures

The semantic relations of words differing in specificity has been modelled in terms of lexical semantic hierarchical structures. Two influential models dealing with levels of conceptual and lexical specificity have been proposed by Miller & Fellbaum (1991) and Rosch (1999; 1976; 1978).

Rosch (1999; 1976; 1978) makes the distinction between subordinate, basic and superordinate level concepts. Examples of this distinction include *tree-oak-red oak* and *furniture-chair-kitchen chair*. In Rosch's terms, a basic level word such as *chair* has high "cue validity", meaning that it has many defining features as compared to its superordinate category *furniture*, but at the same time, it shares fewer features with other members at the same level than the subordinate concept *kitchen chair*. Other characteristics of basic level words include being acquired early in development (Mervis & Crisafi, 1982; Rosch & Lloyd, 1978) and being morphologically simple. It should be noted that determining which level is the basic level is, however, not entirely straightforward. There are, for example, individual differences in which levels function as basic levels depending on expertise (Johnson & Mervis, 1997; Tanaka & Taylor, 1991). Furthermore, not all lexical hierarchies have the same depth of levels. For example, the hierarchy *roadster* → *car* → *motor vehicle* → *wheeled vehicle* → *vehicle* → *conveyance* → *artifact* has more levels than *televangelist* → *evangelist* → *clergyman* → *spiritual leader* → *person*, but fewer than *Shetland pony* → *pony* → *horse* → *equid* → *perissodactyl* → *herbivore* → *mammal* → *vertebrate* → *animal* (Miller & Fellbaum, 1991).

In a manner similar to Rosch (1976), Miller & Fellbaum (1991) assume that noun meanings are organised in a hierarchical manner, from "specific" to "generic". These structures are organised based on lexical relations such as hyponymy/hypernymy, taxonomic sisterhood, meronymy/holonymy. Such lexical structures form the basis of the online lexical database WordNet (Miller, Beckwith, Fellbaum, Gross, & Miller, 1990). An example of a lexical hierarchy from WordNet visualized as a tree structure can be seen in Fig. 3.

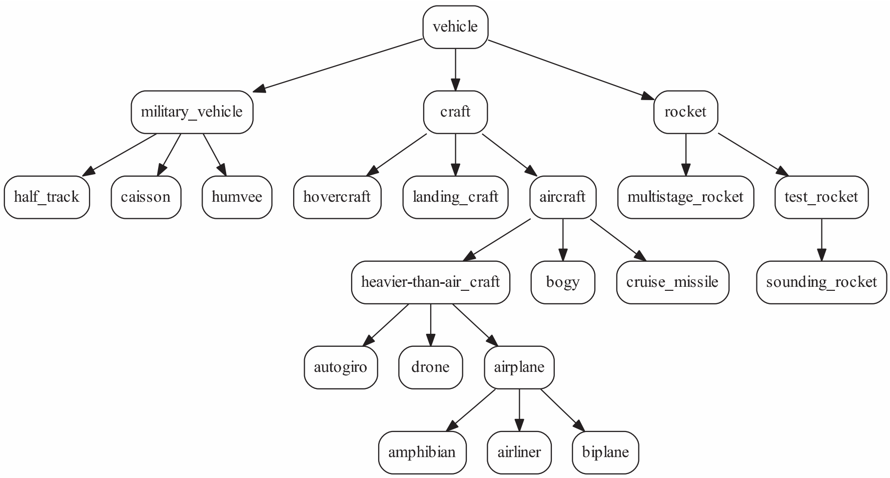


Figure 3
Hierarchical lexical structure from WordNet.

In addition to being more or less associated with defining features, specific and general words also share a "is a" relationship (e.g. a *hammer* is a *tool*). As discussed by Ariel (1990), nouns at more general levels are often used in discourse to refer back to nouns at more specific levels, making antecedent specific concepts accessible through a superordinate concept. For example, whereas the order of the general/specific noun in the example *"My brother bought a German shepard. He just loves the dog"* is perfectly fine, the reversed order is less suitable for creating coherence *"My brother bought a dog. He just loves the German shepard.*" This also relates to Haliday and Hasan's (1976) discussion of general nouns as creating cohesion in discourse.

Relation of hierarchical semantic structures, semantic features and mental images

Miller (1991) as well as Rosch (1999; 1976) describe hierarchical semantic structures where the degree of detail in terms of the number of distinctive features is greater for more specific words. Rosch (1976) proposed that basic level words such as *bird* can be easily distinguished because they have a sufficiently large number of defining features. In comparison, more general, superordinate level words such as *animal* have few distinctive features, whereas specific, subordinate level words such as *magpie* do not have so many extra features compared to the basic level. These models assume that concepts at more specific levels share the defining features of the general levels, but that they also are characterised by additional features (G. A. Miller & Fellbaum, 1991). Like linguistic models including 'semantic features' (Lyons, 1977; Weinreich, 1972) (see 1.1.3) these features may be of different types.

It has been assumed that different levels of specificity are associated with sensory content to varying degrees. This idea was mentioned by Rosch et al. (1976) as well as Miller & Fellbaum (1991), although not extensively elaborated on. The basic level has been suggested by Rosch to be "the most inclusive categories for which it was possible to form a mental image isomorphic to the appearance of members of the class as a whole" (Rosch & Lloyd, 1978), p. 9. An idea which is of importance for the work carried out within the present thesis is that for nouns at more specific levels of categorisation, these mental images could be expected to involve larger numbers of distinct features, many of which may be vision-related. For highly specific/concrete nouns, many defining features are likely to be sensory-related, such as the red colour, round shape, watery structure and specific taste of a *tomato*. As previously outlined in Mårtensson et al. (2011), this particular type of semantic features, related to processing of specific sensory properties (e.g. colour, shape, sound, touch, motion, taste, smell, etc) might be possible to target in terms of neural processing in modality-specific sensory brain regions.

Thus, sensory-relatedness might differ depending on word specificity in two partially related but partially distinct ways: the degree to which words evoke mental images and the degree to which they are associated with sensory semantic features.

1.2.3 Neurocognitive processing and lexical specificity

In addition to studies investigating the neural correlates of abstract and concrete words, neuropsychological research has also targeted possible differences in processing stimuli at different levels of conceptual specificity. In particular, studies involving patients with diagnoses such as SD and aphasia (also described in 1.1.3) have provided insights into how words differing in specificity are differently affected by these conditions. Using a picture naming task, Crutch & Warrington (2008) found that aphasic stroke patients and SD patients differed in opposite directions from the basic level preference in naming seen in healthy individuals. Whereas aphasia was associated with preserved naming performance at the subordinate level, SD patients were relatively more accurate in superordinate level naming. Rogers & Patterson (2007) obtained similar results in a picture categorisation task with SD patients. Furthermore, they found that when healthy participants solved a picture categorisation task, a superordinate level advantage similar to that of SD patients could be induced using very rapid presentation rates. This complicates the picture that the basic level is always privileged in terms of being accessed first, thereby providing access to subordinate and superordinate levels. Consistent with the hypothesis that the anterior temporal lobe, a brain region affected by SD, is important for accessing conceptual information at more specific levels, activity in this area has been shown to be modulated by word specificity, with more specific nouns, as well as general head nouns preceded by more specific modifiers, yielded stronger activation of the left anterior temporal lobe (Zhang & Pylkkänen, 2015).

1.3 Emotion and word processing

1.3.1 Emotion in lexical semantics

The emotional content of words is a challenge to capture and to formalise in a way that allows it to be empirically investigated, given that emotions in themselves, as well as the way words might express them, are very subjective things. One way of describing the role of emotion in lexical semantics is by using the distinction between 'connotation' and 'denotation', briefly mentioned in section 1.1.1. In this view, denotations are the dictionary-like meanings of words, whereas the emotional associations they give rise to in most cases are categorised as connotations[6] (Jackson, 2013; Ullmann 1962). For example, the denotation of the word *war* might be something like "a state of usually open and declared armed hostile conflict between states or nations" (www.merriam-webster.com/dictionary/war). In contrast, fear, shock, sorrow, anger and other emotions likely to be associated with *war* would be seen as connotations. From this view follows the fact that the only words that can have emotional experiences as their denotative meaning are words for actual emotions such as *joy*, *fear*, *anger*) or emotional states (*happy*, *angry*, *sad*). In line with the division of denoting or connoting emotion, Viberg (2008) discusses emotion as being a largely "hidden dimension of the lexicon". He exemplifies this with the word *hit*, which refers to a concrete object coming into contact with another concrete object, but hitting someone implies hurting someone. At the same time as inferences about emotional states can be drawn from words that do not have any explicit emotional menings, Viberg (2008) also notes that basic emotion words such as *happy* and *angry* may be more frequently used to describe rather than express emotions.

In contrast to the division of denotative and connotative meanings assumed in linguistics, emotional words in empirical cognitive psychological research are commonly defined based on subjective ratings of emotional arousal or valence. Thus, the emotional stimuli used in experiments are usually words that are rated high in arousal or as having strongly positive/negative valence (Kousta, Vinson, & Vigliocco, 2009). This delimitation of what is considered an emotional word thus does not take into consideration (or rather, does not really aim to take into consideration) the difference between denotation and connotation. For instance, both *krig* 'war' and *skam* 'shame' may be considered equally high in emotional arousal (both with a rated value of 593 in Blomberg et al. (2015)). What matters in this operationalisation is

---

[6] The notions of 'connotation' and 'denotation' have been extensively discussed and debated (Frege, 1892; Russell, 1905). In the present thesis, they will be used in the broad sense just described, following Jackson (2013).

whether the word ratings reflect an association with a strong and immediate emotional experience.

1.3.2 Neuroimaging studies of emotional word processing

The field investigating the processing and neural correlates of emotional stimuli is vast. In order not to be too extensive, this summary will be limited to studies on emotional words. Emotional words (i.e. words with high ratings of emotional valence and/or arousal) have been suggested to be a category of their own, different from the categories of concrete and abstract words (Altarriba & Bauer, 2004; Altarriba, Bauer, & Benvenuto, 1999). In these studies, the emotional category consisted primarily of adjectives and nouns denoting emotions or emotional states (e.g. *love*, *fear*, *happy*). Alternatively, emotional words can be conceptualised as abstract words with high emotional content (Kousta et al., 2011). Following this line of reasoning, emotional valence can be seen as one important parameter for accounting for abstract word meaning. Emotional content is also included in the model of Paivio (1990), where it is referred to as one type of non-verbal information. The accounts of Paivio (1990) and Kousta et al. (2011), which unlike Altarriba & Bauer (2004) do not conceptualise emotional words as a separate category, would thus differ in their predictions about whether emotional words are more like abstract or concrete words. Following Paivio (1990), the presence of non-verbal information could be expected to put emotional words closer to concrete words, whereas Kousta et al. (2011) rather see emotional information as being a foundational property of abstract words.

In a comprehensive review of studies on written emotional word processing (Citron, 2012), patterns found in behavioural studies as well as results from imaging and electrophysiological studies are summarised. Networks including the medial prefrontal cortex, anterior cingulate cortex, the insula and subcortical regions such as the amygdala have been found to be sensitive to emotional lexical content (Citron, 2012). This activity may be different in neurological conditions which affect emotional and social behaviour. An fMRI study with autistic and typically developing individuals (Moseley et al., 2015) showed less activation in motor and limbic brain regions as a response to emotional words (e.g. *dread*, *hate*, *fear*). In ERP studies, frequently found emotional effects are an early posterior negativity (EPN) peaking 200-300 ms after stimulus onset, and a later posterior effect in the 500-800 ms time-window, often referred to as the late positive complex (LPC) (Citron, 2012; Palazova, 2012; Palazova, Mantwill, Sommer, & Schacht, 2011).

1.4 Hemispheric lateralisation

1.4.1 Concrete/abstract words

Following Paivio's (1990) dual coding theory, abstract words have been hypothesised to be processed by a verbal system in the left hemisphere (LH) only, whereas concrete words have been assumed to also activate non-verbal information, e.g. mental imagery, expected to involve additional activation of the right hemisphere (RH). This idea has been supported by neuroimaging studies showing more bilateral activation for concrete words and greater LH activation for abstract words (Wang et al., 2010). Using a visual half-field presentation paradigm, Huang et al. (2010) compared ERP's for nouns modified by adjectives to be interpreted in a concrete sense (e.g. *green book*) or an abstract sense (e.g. *engaging book*). They found that for LH presentation, the concrete senses were indicated by more positive N400s, which have been suggested to indicate less effortful processing or alternatively, fewer semantic features. This would also be consistent with the hypothesis that sensory information in terms of sensory-related features is more RH lateralised. Further supporting a more prominent role of the RH in concrete than abstract word processing, concrete noun phrases such as *green book* presented to the RH yielded greater negativity in the late N700 time-window, which has been suggested to reflect mental imagery, than abstract noun phrases (*engaging book*). However, results from studies of lateralisation of concrete and abstract words' relative lateralisation do not unequivocally support this idea (Fiebach & Friederici, 2004).

1.4.2 Lexical specificity

Assuming that specific nouns are more strongly associated with sensory information in terms of mental images than general nouns (Rosch et al., 1976), differences between specific nouns such as *carrot* and general nouns such as *vegetable* could be expected to be similar to differences between concrete and abstract words, with a greater involvement of the RH for specific than general nouns. Also using visual half-field presentation, Laeng et al. (2003) found picture categorisation at a more specific level was performed faster by the RH than categorisation of the same pictures on a general level.

However, there is also a literature suggesting that global visual information is processed to a higher degree by the RH whereas local visual details are more LH lateralised (Navon, 1977). The stimuli often used, the Navon stimuli, are global letter shapes composed of many local letters (see Fig. 4).

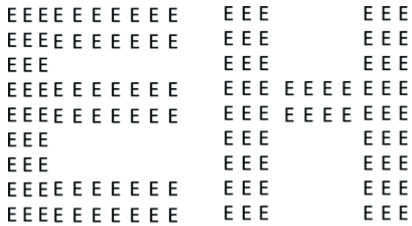


Figure 4
Examples of Navon stimuli (Watson, 2013). Reprinted under the Creative Commons Attribution licence.

1.4.3 Emotional content

Emotional processing has previously been related to the right hemisphere (RH). Greater involvement of the RH in emotional processing has been more consistently found than hemispheric differences related to concreteness or specificity. Relatively stronger RH activation has been seen for emotional prosody (Buchanan et al., 2000), as well for words with emotional content (Borod, Andelman, Obler, Tweedy, & Wilkowitz, 1992). However, the task may also influence lateralisation of emotional words. Abbassi, Blanchette, Ansaldo, Ghassemzadeh, & Joanette (Abbassi, Blanchette, Ansaldo, Ghassemzadeh, & Joanette, 2015) suggest that superficial processing of emotional words activates the LH whereas deep processing involves the RH.

1.5 Summary

As described in the above sections, there is an extensive body of psychological research comparing concrete and abstract word meaning with reference to parameters such as imageability and concreteness, relating their differences to differences in cognitive processing and neural activity. There has, however, been less focus on certain linguistic aspects of concreteness such as degree of lexical semantic specificity, and few attempts to build neurolinguistic models of word meaning. Furthermore, the broad categories of concrete and abstract words previously compared includes a wide variety of different words, making a more fine-grained analysis of lexical semantic categories well-needed. The notion of semantic feature in linguistic semantic analyses has encompassed meaning properties on different levels of abstraction, whereas results from neuroscience indicate that the study of semantic features in relation to word meaning processing could benefit from being narrowed down to the set of features related to sensory and motor processing.

1.6 Research questions of the present thesis

The overall goal of the present thesis was to shed more light on the representation and processing of nouns differing in their degree of concreteness. In order to do so, linguistic and psychological approaches accounting for word meaning were brought together with a large field of empirical research relating concrete and abstract word processing to brain function.

Four empirical studies were carried out, targeting different aspects of the production and perception of nouns varying in concreteness. Three concreteness-related word properties focused on in the investigations: imageability, semantic specificity and emotional content. Varying these properties resulted in comparisons of two subcategories of concrete nouns (SPECIFIC and GENERAL) and two subcategories of abstract nouns (EMOTIONAL and ABSTRACT). Central research questions were whether these four word categories would be differently related to sensory (most prominently, visual) information and whether differences in lexical semantic content could be related to different patterns of neural processing.

Paper I was concerned with the overall research question of whether lesions to primary sensory cortex can selectively impair processing of words with meanings related to a particular sensory modality. The study involved a semantic analysis of semi-spontaneous discourse produced by a person with lesions in visual (occipital) brain regions. Based on models assuming large numbers of distinguishing semantic features for highly specific nouns, visual features were expected to be particularly crucial for the interpretation of concrete, highly specific nouns. The hypothesis was thus that words rich in visual information would be selectively impaired following lesions in visual cortex.

For Paper II, the main research question was methodological: Can subjective ratings of cognitive psychological variables – more specifically imageability, familiarity and age of acquisition – be reliably transferred from English to Swedish?

The research question explored in Paper III was whether nouns differing in emotional arousal, imageability and lexical specificity would involve the left and right hemispheres to different degrees. Two concrete subcategories (SPECIFIC and GENERAL) and two abstract subcategories (EMOTIONAL and ABSTRACT) were compared using a dichotic listening paradigm[7]. Based on studies suggesting a prominent role of the RH in both emotional and visuospatial processing, SPECIFIC as

[7] See paragraph 2.2.2 for further description of the dichotic listening method.

well as EMOTIONAL word processing was hypothesised to be more RH lateralised in contrast to GENERAL and ABSTRACT word processing, which was hypothesised to be measureable in terms of relatively shorter response times for left ear presentation for EMOTIONAL/SPECIFIC words.

Following up on the distinctions made in Paper III, Paper IV further compared the processing of SPECIFIC, GENERAL, EMOTIONAL and ABSTRACT words as well as PSEUDOWORDS. Measures of neural activity were obtained using EEG during a lexical decision and an imageability rating task. The study targeted two ERP components previously shown to be different for concrete words, abstract words and pseudowords: the N400 and the N700. The suggestion was made that the number of words associated with a particular test word might modulate the N400 amplitudes. Nouns differing in lexical specificity but matched in imageability were also targeted, with the aim of seeing whether differences in the brain's response to different levels of specificity would be present without differences in imageability.

2. Methods

2.1 Behavioural measures

2.1.1 Word ratings

Papers II and IV of this thesis (Blomberg & Öberg, 2015; Blomberg, Roll, Lindgren & Horne (manuscript) both specifically focused on word ratings; in particular, imageability ratings (IR). In addition, IR data have been crucial for determining the stimuli sets in all of the studies, just as they have been for a large number of previous studies comparing abstract and concrete words. Given the central role of IR, this section will begin with a description of the IR procedure and its advantages and limitations. In Paper II, ratings of emotional arousal, age of acquisition (AoA) and familiarity were also obtained.

Imageability ratings (IR)

IR are a way to quantify the degree of sensory information associated with words, more specifically, to capture how easily a word gives rise to mental imagery. Following Paivio, Yuille & Madigan (1968), the instructions for IR are to estimate on a 1-7 point scale how quickly and easily a word evokes a mental image, i.e. "a mental picture, or sound, or other sensory experience". IR are highly correlated with concreteness ratings, which measure on a similar 1-7 point scale the degree to which words refer to objects, persons or materials which can be perceived with the senses (Stadthagen-Gonzalez & Davis, 2006). Nevertheless, there are differences, with some words being rated high in concreteness but still low in imageability, (Simonsen, Lind, Hansen, Holm, & Mevik, 2013); this might, for example, be the case with words that are unfamiliar or infrequent. In the work carried out within the present thesis, IR were chosen since they can be assumed to be more directly associated with activation of sensory information associated with words, as compared to concreteness ratings which measure the degree to which words refer to concrete objects/entities.

It has been questioned whether IR only tap into the degree of mental imagery or if they also measure other factors. Westbury et al. (2013) suggested that imageability effects can be explained to a substantial degree by the factors 'context' and 'emotionality', which they found support for using an algorithmic method for predicting imageability from these two factors. There have also been discussions regarding the different sensory modalities included in IR. In short, although the instructions specify that a mental image can be of any sensory modality, IR might be more likely to capture the visual content of words than the sensory content of other modalities. This has lead to extensions such as modality-specific ratings (Lynott & Connell, 2012).

Emotional arousal ratings

Emotional content is usually quantified along the dimensions of arousal or valence. Arousal can be rated on a Likert-type scale ranging from for instance 1-7, where low values represent words which do not evoke strong emotional experiences. Emotional arousal thus measures the strength of words' emotional content but does not take the polarity (positive or negative) into account. Words can also be rated for emotional valence, with negative values corresponding to negative words, 0 to completely neutral words and positive values to positive words (Kensinger & Schacter, 2006). In the present thesis, arousal ratings rather than valence ratings were collected for two reasons: First, arousal ratings were carried out in the same experiment (Paper II) as imageability, familiarity and AoA ratings. Since these are all quantified on 1-7 Likert scales, using a similar scale to quantify emotional content was considered to be less likely to cause confusion during word ratings and would make the ratings more easily comparable. Secondly, there is support for arousal being a more important factor affecting word processing (Kensinger & Schacter, 2006; Kousta et al., 2009) (although some effects also seem to be valence-dependent (Kanske & Kotz, 2007)).

Age of acquisition (AoA) ratings

AoA ratings were also collected and compared to English ratings, since AoA is a factor known to have an impact on word processing, making it a variable which it might be beneficial to be able to control for. However, since AoA is a factor that is highly correlated with imageability, it is difficult to design an experiment where one of these factors is systematically varied, whereas the other is at the same time held constant (Cortese & Khanna, 2008). Given this difficulty, in combination with a very limited number of AoA ratings available for words which also had emotional arousal and imageability ratings, no attempts to match stimuli for AoA were made.

Familiarity ratings

Familiarity ratings were obtained in Paper II. The choice to collect ratings of familiarity was based on the fact that it could be a good alternative and complement to word frequencies, which may differ in how well they reflect everyday experience with words, depending on the sources of the corpora they are taken from. Mainly because of the same reason as AoA – correlations with imageability and a limited dataset with words rated for emotional arousal and imageability which also had familiarity values – further analyses did not include familiarity.

The word rating procedure

In the work presented in the present thesis, word rating data was collected using three different methods. In Paper II, word ratings were collected using a web-based interface. Four properties – imageability, AoA, familiarity and emotional arousal – were rated for each word. The same trial thus involved rating four different properties before moving on to the next trial. In Paper III, ratings of emotional arousal only were obtained using E-prime (2012), following the dichotic listening experiment. Finally, for Paper IV, some words already had ratings of imageability and emotional arousal from the two previous word rating experiments. In order to obtain ratings of both parameters for all words, a group of 23 Swedish participants (12 female) not taking part in the ERP experiment rated a subset of the stimuli words (which did not have values from the previous data collections), first for emotional arousal and then for imageability. For these ratings, see Appendix 1.

2.1.2 Free oral descriptions of word meanings

In Paper I (Mårtensson, Roll, Lindgren, Apt, & Horne, 2013), healthy and aphasic participants were presented with the task of describing the meanings of concrete, abstract and emotional words freely and in as much detail as possible. The task was similar to the one used by Barsalou & Wiemer-Hastings (2005), (see also section 1.1.4), but with the difference that a larger number of stimuli, matched for different variables including word class, were tested. In this task, the instructions were to provide as much information related to the test word as possible, bearing in mind that there are no right or wrong answers.

The task of providing free descriptions and analysis of semi-spontaneous speech has not been used extensively with aphasic participants (one notable exception is (Crutch & Warrington, 2003)). Rather, tests assessing the single word level such as naming from pictures or from definitions have been the more common methods (Crutch & Warrington, 2003). These tests require the participant to access and produce a certain target word, a task which is particularly difficult for an anomic person. There are also some tests focused on word definitions, e.g. the Wechsler Adult Intelligence Scale (WAIS) vocabulary test, where definitions are scored depending on to what extent they capture word meaning. However, since the goal in Paper I was to investigate the production of words semantically related to the test words in semi-spontaneous discourse, word definitions would be likely to make the participants too restricted in only providing the information that was correct or relevant. Word associations (single words produced for concrete and abstract test words) were previously investigated (Mårtensson 2011, 2008), but were found to be difficult, in particular for aphasic participants and with abstract words.

Coding of the descriptions

The audio-recorded word descriptions were transcribed and a coding scheme was developed for Paper I, with the purpose of capturing the degree of sensory information in the content words present in free oral descriptions of the meanings of highly concrete testwords. It should be emphasised that the coding scheme only aimed to capture a) content words with a hierarchical semantic relation to the test word and b) content words which described physical properties of test words referents. Thus, this particular coding was only applicable for concrete test words.

Early attempts to develop a coding scheme suitable for analysis of concrete as well as emotional and abstract test words also involved codes for capturing other aspects of information associated with the test words, such as the degree of personal/general information present in the descriptions. The development of such coding schemes was, however, temporarily set aside, mainly due to Paper I's focus on concrete information, but also because of difficulties segmenting the material in a way which could allow quantitative analyses of e.g. the degree of personal/general content. Further discussion of problems related to data-coding and some suggestions for solutions are presented in 5.2.2.

2.1.3 Response time (RT) measurements

Response times (RTs) are assumed to reflect the cognitive effort involved in solving a particular task. Although RTs do not provide any direct insights into what happens before the button press, they can still give some indication of whether there are differences in the cognitive processing of different stimulus types. Thus, response times were measured in Paper III, where it was the main quantitative measure for studying test persons' categorisation of words as 'concrete' or 'abstract', as well as in Paper IV, where it accompanied the event-related potentials (ERPs) and measured the time it took for test persons to make decisions on lexicality as well as to rate test words' imageability.

2.1.4 Semantic categorisation

Making categorisations based on semantic properties of words, e.g. whether they refer to something concrete/abstract, living/non-living, familiar/unfamiliar, are all tasks involving explicit access to semantic information. An advantage with explicitly targeting semantic knowledge is that differences between stimuli types may be more likely to be captured under such conditions, compared to more shallow tasks (Sabsevitz et al., 2005). For example, a focus on making form-based evaluations such as searching for a particular letter or deciding whether words are written in an upper- or lower case font diverts participants' attention from tapping into semantic processing and might decrease the likelihood of semantics-related differences shining through.

The other side of the coin is, of course, the fact that tasks requiring explicit access to semantic information also have disadvantages. For example, focusing on specific semantic properties of the stimuli is likely to activate processes that are not always involved in ordinary language usage. Thus, the effects obtained could run the risk of being epiphenomenal. It is also the case that the task of making decisions based on semantic properties are more likely than those based on form-based properties to be interpreted differently by different subjects, which could result in the use of different strategies to solve the task. Finally, if the semantic property targeted by the questions is the same property one wants to investigate, this could also introduce a bias in the effects. On the other hand, if another property is targeted, the one under investigation may be attenuated.

Semantic tasks were involved in all of the studies included the present thesis: describing word meanings in Paper I, ratings of word properties in Paper II, abstract/concrete categorisations in Paper III, and imageability ratings in Paper IV. Paper IV additionally included a task less explicitly targeting semantic information – lexical decision, which will be further described below.

2.1.5 Lexical decision (LD)

In a visual lexical decision (LD) task, written words and pseudowords (phonotactially legal letter strings not existing in the language under investigation) are presented and the task is to decide whether the perceived stimulus is a word or not. In contrast to semantic judgment tasks, the LD task does not require taking previously specified semantic information into account. Response times in LD are usually longer for concrete than abstract words (Kroll & Merves, 1986), but this difference may disappear if concret and abstract words are put into context (Schwanenflugel et al., 1988) or matched for emotional valence (Barber et al., 2013). It is not entirely clear to which degree LD taps into semantic processing, but the LD task is likely to require at least lexical access. The lexical decision task was chosen in Paper IV as a way to compare the word categories during more automatic processing in contrast to the imageability ratings, which were expected to give rise to more elaborate semantic processing.

2.2 Neuropsychological methods

2.2.1 Patient studies

Since the foundational work of Broca (1861) and Wernicke (1874), investigations of language processing in persons with brain lesions or other types of neurological disorders have been widely used to gain knowledge about the neural correlates of linguistic and other cognitive abilities. In persons with aphasia, different aspects of language processing (e.g. phonology, syntax, semantics, pragmatics) can be affected depending on lesion localisation. Very generally speaking, whereas left anterior lesions most often affect speech production and syntax, left posterior lesions are likely to implicate greater problems with speech perception and semantics. Anomia, i.e. difficulties accessing and producing content words, occurs in almost all people with aphasia to some degree in combination with other language-related problems. However, anomia can sometimes be an isolated symptom, in which case the diagnosis is anomic aphasia (Ahlsén, 2006).

Semantic categories and anomia

Semantic categories may be differently affected in anomia. In addition to problems with concrete/abstract words or words belonging to specific sensory modalities, such as those described in sections 1.1.2 and 1.1.3, categories such as natural objects may be selectively impaired as compared to man-made objects (Warrington & Shallice, 1984). The explanation for this might be differences in what type of information constitutes their distinctive features (e.g. perceptual/functional) (Tyler, Moss, Durrant-Peatfield, & Levy, 2000; Warrington & Shallice, 1984). Alternatively, semantic categories such as natural and man-made objects might be dissociable mainly based on evolutionarily salient distinctions (Caramazza, 1998). Relating such selective impairments of certain semantic categories to the localisation of the brain lesions can provide important information of the neural processing of these categories. Paper I investigated processing of concrete nouns in a person with lesions in visual (occipital) cortex, previously diagnosed with anomia. The hypothesis that words with visual-related semantic content would be more impaired was tested.

The case study approach

Although group studies are necessary in order to make strong generalisations, the case study also has several advantages (Caramazza, 1984). One motivation behind choosing a case study is, of course, for practical reasons. Assuming that the goal of a study is to be able to relate a specific lesion location to a certain behavioural pattern, this may be complicated by the fact that it is often difficult to find large groups of participants with similar lesion locations, in particular for focal lesions or lesions in a region of the brain which is not frequently affected. This was the case with the participant in Paper I, whose lesion due to a posterior cortical artery stroke was less common than the mid cerebral artery strokes usually leading to aphasia. Furthermore, although a case study is limited in generalisability, case studies can nevertheless be very informative. For example, if it is hypothesised that a lesion in a certain area gives rise to a specific behavioural impairment, it only takes one patient with the same lesion not exhibiting the impairment to call the hypothesis into question. A case study also provides the opportunity to describe the characteristics of the test person in greater detail than is often the case with more quantitative approaches.

2.2.2 Dichotic listening

The dichotic listening method

Dichotic listening has been extensively used to investigate lateralisation of different types of cognitive processing, e.g. the degree to which the two hemispheres process language and visuospatial information (Hugdahl, 2000). Many dichotic listening studies have focused on the processing of single syllable consonant-vocal (CV) stimuli such as *ba*, *da*, *ga* etc (Thomsen, Rimol, Ersland, & Hugdahl, 2004). The assumption behind dichotic listening is that linguistic information is processed mainly by the left hemisphere (LH). The dichotic listening method makes use of the anatomy of the neural connections between ear and brain, where the main part of the pathways are crossed, so that information presented in an ear reaches the contralateral hemisphere faster (Fig. 5). Thus, when competing linguistic stimuli are presented to the left and right ear, the participant is more likely to report having heard the stimulus presented in the right ear, which reaches the LH faster.

Figure 5
Dichotic presentation of a word (*fågel* 'bird') and a pseudoword (*figar*) used in Paper III. Figure adapted from Hugdahl, Løberg and Nygård (2009).

Hemispheric lateralisation of emotional and visual processing

Although CV syllables have been widely tested in dichotic listening tests, there has also been a handful attempts to investigate semantic processing by means of dichotic listening, some of which have focused on emotional, abstract and concrete word content (Ely, Graves, & Potter, 1989; Kadesh, Riese, & Anisfeld, 1976; Prior, Cumming, & Hendy, 1984). These studies tested the hypothesis that the LH would be relatively more involved in the processing of abstract as compared to concrete and in one case (Ely et al., 1989) emotional words, yielding mixed results. A paradigm similar to that of Ely et al. (1989) was used in Paper III, extended to also include the distinction of SPECIFIC-GENERAL nouns.

2.2.3 Event-related potentials (ERPs)

Using electroencephalography (EEG), the electrical activity in the brain can be measured in terms of changes in voltage over the scalp over time. Event-related potentials (ERPs) are neural responses time-locked to specific cognitive, sensory or motor events. The ERP method is excellent in the time-domain, where it can provide information about the time-course of processing at a millisecond level, but less sensitive to spatial differences in neural activation (Luck, 2014). Thus, the latency and amplitude of ERP components are of main interest. Their distribution over the scalp is, however, also taken into account, since it can be used to identify specific components, although it should not be seen as directly reflecting the sources of the neural processing giving rise to these components.

The ERP method was employed in Paper IV of the present thesis, in order to obtain more information of the processes involved when accessing semantic information related to SPECIFIC, GENERAL, EMOTIONAL and ABSTRACT words. The focus was on two ERP components that have previously been seen to be sensitive to concreteness: the N400 and the N700.

N400

The N400 is a well-known negative-going ERP component peaking around 400 ms after stimulus onset (Fig. 6). It was first seen in sentences ending with an anomalous word, such as "I take my coffee with cream and *dog*." (Kutas & Hillyard, 1980). The N400 has since then been found to be generally larger for more unexpected stimuli in different tasks. For example, it can be diminished by priming a target word with a semantically related word, increasing the predictability of the target. The N400 is also greater for pseudowords as compared to real words and for infrequent words as compared to frequent words (Lau et al., 2008). Of main interest for the present thesis, the N400 is also more negative for concrete words than abstract words (Barber et al., 2013; Gullick et al., 2013; Kounios & Holcomb, 1994; Nittono, Suehiro, & Hori, 2002). However, given that concrete words consistently have been found to be processed with greater speed and accuracy than abstract words (Paivio, 2010), an interpretation in terms of predictability is not straightforward.

There are two main accounts explaining N400 effects: the "facilitated integration view" and the "lexical view" (Lau et al., 2008). The former suggests that the N400 is modulated by the ease with which a stimulus can be integrated into context. The latter interprets the N400 as reflecting the activation of semantic features in long-term memory during lexical access. As discussed in Lau et al. (2008), results from a considerable number of imaging (fMRI and MEG) studies provide support for the lexical access view, all showing activation of the posterior middle temporal cortex, an area known to be involved in lexical access. However, despite the support for the lexical access view, they do not rule out the possibility that integration processes might also contribute to the N400.

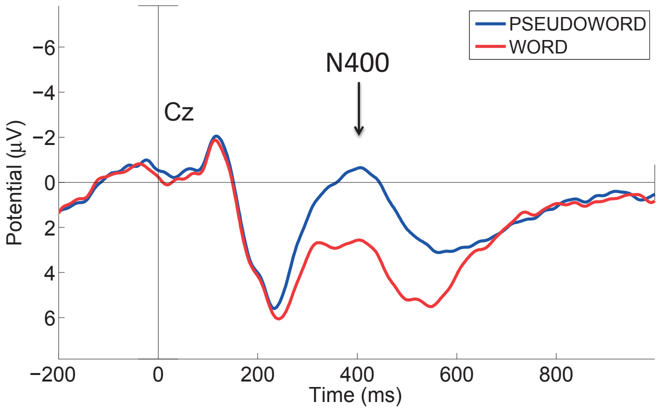


Figure 6
N400 for words compared to pseudowords.

N700/LPC

In comparisons of concrete and abstract words, the N400 has frequently been seen to be followed by a late negative component, starting around 500 ms, lasting until 800-900 ms post stimulus onset (Barber et al., 2013; Gullick et al., 2013; Kounios & Holcomb, 1994; Nittono et al., 2002; Welcome et al., 2011; West & Holcomb, 2000). This component, which similarly to the N400 is more negative for concrete words, was named N700 by West & Holcomb (2000) and has been most consistently found in tasks requiring mental imagery. The N700 occurs in the same time-window as a positive-going component related to emotional content called the late positive complex (LPC), which, however has a more posterior topography (Citron, 2012).

2.3 Stimuli

2.3.1 Concrete (specific/general) nouns

The concrete stimulus nouns investigated in Papers I-II were all nouns that were expected to be related to detailed visual information in terms of colours and shapes, as well as in some cases sensory information of other modalities (e.g. *wolf*, *cauliflower*, *diamond*). The concrete nouns were high in imageability. Nouns referring to animate beings as well as natural and man-made objects were included in approximately equal numbers in order not to bias processing to one or the other of these categories. These nouns belong to what will be distinguished in Papers III and IV as the SPECIFIC noun category. The reason for including this relatively homogenous group of nouns was to make it likely that the stimulus set used in Paper I would be strongly related to visual semantic information.

2.3.2 Emotional nouns

In all four papers, emotional nouns were also distinguished. These were defined as being high in emotional arousal. All stimuli sets consisted largely of nouns similar to the EMOTIONAL category in Papers III-IV. One difference was that all of the emotional words in Papers I-II denoted emotions (e.g. *glädje* 'happiness', *ilska* 'anger' and *curiosity* 'nyfikenhet'), whereas in Papers III-IV, nouns with strong emotional connotations were also included (e.g. *krig* 'war', *död* 'death', *framgång* 'success', *belöning* 'reward'). One reason for this was that word length was decided to be more limited in the psycho- and neurolinguistic experiments in Papers III and IV. Using not only nouns denoting emotions, but also nouns that connoted emotion, made it less difficult to create stimulus lists which were matched for all other variables and were sufficiently high in emotional arousal. In addition, following previous studies, emotional arousal was assumed to have a major influence on word processing.

2.3.3 Abstract nouns

Many of the abstract nouns used as stimuli in all four studies were similar to the ones Schmid (2000) categorises as 'shell nouns' (e.g. *fact*, *problem*, *theory*). However, since shell nouns are a functionally delimited category and not investigated in Swedish, they are not labeled as such and the category as a whole also contains other types of abstract nouns. The abstract noun category was delimited by having low imageability values and also relatively low emotional arousal values.

2.3.4 Other considerations

Two studies used auditory presentation of the stimulus nouns (I and III), the other two (II and IV) used written presentation. The reason for not keeping the mode of presentation constant was that the different studies were carried out as similarly to previous studies as possible. In study I, stimuli were presented orally since written stimuli would have been unsuitable due to the test person's reading difficulties. Study II followed the procedure of a majority of other word rating studies, presenting written words. Study III used a dichotic listening technique, making auditory presentation necessary (but of course a visual hemifield procedure would have been another option to test hemispheric differences). In Study IV, written stimuli were used, in line with previous studies targeting concreteness-related ERP effects.

Word frequencies were taken from the Stockholm Umeå corpus (SUC), a one million, balanced, written Swedish corpus (Ejerhed, Källgren, Wennstedt & Åström, 1992). This corpus was chosen mainly because it is tagged for lemma and word class, making it possible to obtain lemma frequencies related to nouns. A Swedish spoken language corpus does exist (the Gothenburg Spoken Language Corpus (GSLC) (Alwood, 1999) but it is not tagged and also contains fewer words, limiting the number of stimuli which could be found in it.

3. The investigations

3.1 Paper I

Paper I (Mårtensson et al., 2013) targeted the role of sensory semantic features in word processing by looking at how modality-specific (visual) lesions affected the comprehension and expression of concrete word meanings. An analysis was carried out on the semantic content of free oral descriptions of word meanings. In focus for the study was a participant (ZZ) with lesions in visual (left occipital) regions of the brain. Unlike healthy controls, as well as aphasic controls with lesions in other areas, ZZ showed severe difficulties producing descriptions for concrete words. This pattern of impairment in combination with the lesion localisation led to the conclusion that ZZ's anomic aphasia was likely to be sensory-specific, resulting from an inability to access words with strongly visual-related meanings. An analysis of ZZ's concrete word descriptions showed that compared to controls' descriptions, they contained very few vision-related words (e.g. *blue*, *striped*), but a relatively large proportion of sound-related words (e.g. *talks*, *squeaks*) as well as movement-related words (e.g. *flies*).

Although Paper I focused on descriptions of nouns, parallels can be drawn to Viberg's (Viberg, 1983; 2015) implicational scale of perception verbs (*see* > *hear* > *touch* > *taste, smell*) and the cross-linguistic study of San Roque et al. (2015) who found that vision-related words were consistently more frequent across languages. The pattern of sensory modalities exhibited in ZZ's production could be interpreted as showing that he, having lost access to words which are fundamentally related to visual information, instead made use of words related to other sensory modalities. This allows for some speculation about why sound-related words were ZZ's most frequently produced concrete words. Following the implicational scale of perceptual verbs belonging to the different modalities proposed by Viberg (1983), hearing is the next most important sense related to lexical semantics. Thus, provided that the implicational scale for verbs would be applicable to nouns, it would be supported by the fact that sound-related words were used most frequently by a person whose vision processing was impaired. However, looking further into the distribution of words related to each sensory modality produced by ZZ and the healthy controls, there are also differences from Viberg's (1983) scale for verbs. First, the controls did not produce a large degree of sound-related words, but rather more touch-related words. This is likely to have to do with the fact that the stimuli were concrete nouns with many defining visual features and only few defining auditory features. Second, it would be predicted from Viberg (1983) that touch-related words would be the third most frequent. However, ZZ produced touch-related words only to a small degree. In line with this, it has been seen that visual and tactile features are more closely related. Lynott & Connell (2012) collected word ratings of modality-specific perceptual experiences and found that the ratings of vision and touch were strongly correlated. This might be because many entities that can be seen are also touched. In their study, words rated high in the auditory domain were the most distinct from words rated high in sensory content from the other modalities.

The hierarchically related content words ZZ did produce were at very general levels (e.g. *animal*, *thing*, *species*) as opposed to more specific levels (*bird*, *magpie*). This supports the suggestion that concepts on specific levels of categorisation are more related to sensory information, which could be related to a stronger association with mental imagery, as well as with being defined by larger numbers of sensory (visual) features (Rosch et al., 1976).

The fact that lesions to primary visual cortex can selectively impair the processing of vision-related words generates the prediction that this also may be the case with lesions to primary sensory cortices in general. Supporting this idea, Trumpp et al. (2013) found that lesions to auditory areas selectively impaired the processing of sound-related concepts. Findings like these are very much in line with the accumulating evidence that the processing of concrete nouns referring to perceivable objects or verbs referring to bodily actions activate sensory and motor areas of the brain (Pulvermüller & Fadiga, 2010).

Another study published the same year (Friedmann, 2013) described a very similar case, a Hebrew speaker with left occipital lesions who was impaired with highly imageable words, but not with abstract words. Furthermore, his naming ability of pictures of objects was restricted to the superordinate level.

3.2 Paper II

Paper II (Blomberg & Öberg, 2015) investigated whether the ratings of three word properties – imageability, familiarity and age of acquisition – were comparable for English and Swedish. A sample of Swedish nouns with ratings of these properties was shown to correlate well with the ratings of their English translations, in particular for imageability and age of acquisition. Paper II thus demonstrated that translating word ratings of the properties in question (at least from English to Swedish) is an acceptable method when Swedish ratings are not available. Being able to use the large English databases of words with ratings of these psycholinguistic variables, makes it easier to design studies in Swedish in the absence of Swedish word ratings. However, it is also concluded in the paper that a Swedish database would be ideal. One reason for this is that not all word meanings translate equally well.

3.3 Paper III

Based on the finding in Paper I that different lexical semantic levels seemed to be affected differently following lesions to the visual cortex, the three semantic categories (concrete, emotional and abstract) in study I (following e.g. Altarriba & Bauer (2004)) were expanded to four different categories including two concrete categories (SPECIFIC, GENERAL) and two abstract categories (EMOTIONAL and ABSTRACT) in Paper III (Blomberg, Roll, Lindgren, Brännström, & Horne, 2015). SPECIFIC words were assumed to be more associated with visual information than GENERAL words, an assumption which was supported by higher imageability ratings for SPECIFIC words. Paper III compared the processing of SPECIFIC, GENERAL, EMOTIONAL and ABSTRACT words by means of an analysis of response times and accuracy in a dichotic listening task involving deciding whether test words were 'concrete' or 'abstract'. It was hypothesised, following previous studies showing RH advantages for the processing of specific images (Laeng et al., 2003) as well as emotion (Borod et al., 1992), that decisions for the the EMOTIONAL and SPECIFIC testwords would both be relatively faster when presented in the left ear.

The clearest result from Paper III was that EMOTIONAL words were processed faster than the other testword categories when presented in the left ear.[8] This was taken as support for the hypothesis that EMOTIONAL (as compared to non-emotional) word processing is relatively more dependent on processing in the RH. A similar prediction was made for SPECIFIC words, based on the idea that the RH is better at processing visual information, seen as faster naming of pictures at more specific levels when presented to the left visual field (RH) (Laeng et al., 2003; Paivio, 1990). This idea was not, however, supported. SPECIFIC words presented to the left ear/RH actually yielded long response times, on par with those of ABSTRACT words. For right ear/LH presentation, a concreteness effect was seen in response times, with response times decreasing as imageability increased. The fact that response times for SPECIFIC words were short for left ear/RH presentation and long for left ear/RH presentation might be interpreted in a manner in line with the literature on global and local visual processing of visual stimuli (Fink et al., 1996). Given that the LH might be specialised for visual processing of local details, response times should be longer for words semantically related to visual details presented in the left ear/RH. This is in fact also more in line with the results from the data from Paper I, where left occipital lesions were associated with difficulties accessing highly imageable words.

[8] Please note that in the key to Figure 1, 'left' and 'right' have been erroneously reversed.

Given the complexity of the dichotic listening task which yielded long RTs, the interpretation of the results was not straightforward. This was addressed in the following study (Paper IV) using EEG methodology.

3.4 Paper IV

Paper IV (Blomberg, Roll, Lindgren & Horne, manuscript) investigated neurophysiological patterns associated with the same noun categories as in Paper III (SPECIFIC-GENERAL-EMOTIONAL-ABSTRACT), and in addition, PSEUDOWORDS. More specifically, the study aimed to see whether these categories differed in two ERP components previously related to concrete and abstract words, the N400 and the N700 (described in 2.2.3). In order to investigate more automatic processing as well as processing related to explicit activation of sensory information, the same participants performed a lexical decision task as well as an imageability task. Based on previous studies finding larger N400 amplitudes for pseudowords than real words, and larger amplitudes for concrete than abstract words, the N400 was hypothesised to be smaller in the direction PSEUDOWORDS > SPECIFIC > GENERAL > EMOTIONAL > ABSTRACT. The N700 has been suggested only to be present in imagery-demanding tasks (West & Holcomb, 2000), but was nevertheless found in the lexical decision task as well as the imageability rating task in Paper IV.

Since previous explanations for the N400 in terms of word predictability (larger amplitudes for less predictable stimuli) or semantic feature activation (larger amplitudes for stimuli with more semantic features) do not fully explain such a pattern with diminishing negativity going from PSEUDOWORDS to SPECIFIC, GENERAL, EMOTIONAL and ABSTRACT word categories, a proposal for accounting for the N400 effect was made on different grounds. It was assumed that increasingly abstract words have larger numbers of lexical associates and that this is a main factor modulating the N400.

Results showed that N400 amplitudes largely followed the predictions, with the N400 being the largest for PSEUDOWORDS, followed by SPECIFIC nouns. Differences were less widespread for comparisons involving GENERAL-ABSTRACT and EMOTIONAL-ABSTRACT words, indicating that they all may be relatively abstract. The fact that clear differences in the N400 could be seen for SPECIFIC as compared to GENERAL nouns is interesting given the fact that they both often are considered to be concrete and have relatively high imageability ratings. The EMOTIONAL-ABSTRACT categories differed in the opposite direction of what would be expected based on imageability, with the EMOTIONAL category having the smallest N400 amplitudes.

Taken together, the results of Paper IV indicate that N400 amplitudes differ in a way which is not straightforwardly explained by the contextual integration view or the lexical view of the N400, but which can be explained by assuming that the number of lexical associates increases with increasing abstractness. This is in line with models proposing that abstract words are organised conceptually based on associative relationships, in contrast to concrete words which are organised taxonomically based on semantic similarity to other concepts (Crutch et al., 2009). The results are also compatible with theoretical accounts suggesting that abstract word meanings are contextually determined (Schmid, 2000).

4. Conclusions

4.1 Principal findings

Paper I involved a semantic analysis of content words in semi-spontaneous discourse produced by a person with lesions to primary visual cortex (left occipital lobe). In contrast to the test person's processing of abstract and emotional word meanings, access to concrete word meanings was shown to be selectively impaired. This pattern of performance was interpreted as a result of an inability to access visual semantic features crucial for concrete word processing. When vision-related words could not be accessed, sound-related words seemed to be used more often, as would be expected based on the sensory hierarchy proposed by Viberg (1983). The fact that concrete word processing can be severely impaired while abstract word performance is normal, suggests that grounding of abstract meanings in concrete meanings (Lakoff & Johnson, 1980) may at least not be necessary for using and explaining the meanings of abstract words in adults when the concepts have been acquired. The fact that the participant with occipital lesions only produced non-specific nouns provided support for the idea that specific nouns are more related to sensory (in this case visual) features (Rosch et al., 1976) than less concrete words are.

Paper II presented data on ratings of word properties, which are of relevance to researchers carrying out psycholinguistic research in Swedish. The study showed that English and Swedish word ratings of imageability and age of acquisision are highly correlated. Thus, Paper II provided support for transferring ratings from English databases to Swedish translations of the words, although differences may still be present between the two languages for individual words. Since no organised database containing Swedish word rating data currently exists, it is suggested that such a database should be compiled.

The main finding from the dichoting listening study in Paper III was that EMOTIONAL words were processed relatively faster when presented in the left ear. This replicates previous studies showing that emotional words are processed relatively easier than non-emotional words presented to the left ear/RH. Long RTs for SPECIFIC words presented to the left ear suggested, in contrast to the hypothesis, that the processing of SPECIFIC words did not involve additional RH activation. Instead, the long left-ear RTs may actually indicate that SPECIFIC nouns were relatively more LH localised, although this hypothesis would have to be tested in further studies.

Paper IV found a pattern of N400 amplitudes going from high to low in the direction PSEUDOWORD – SPECIFIC – GENERAL – ABSTRACT – EMOTIONAL and proposed a novel model accounting for the direction of these differences. Previous models have suggested that the N400 can be explained by contextual integration or activation of semantic features (Lau et al., 2008). Paper IV tested the alternative hypothesis that the N400 rather reflects the number of associated words in the mental lexicon. This would be expected based on models assuming that abstract word meanings are more determined by contextually/associatively related words (Crutch et al., 2009; Schmid, 2000; Schwanenflugel & Shoben, 1983). N400 effects were expected to be greatest for PSEUDOWORDS which should have no semantically associated lexical items, and decrease with increasing test-word abstractness. The results supported this assumption.

Another contribution of Paper IV was that it related the difference in semantic specificity in the hyponymy relation in lexical semantic models to variations in N400 amplitude. The categories SPECIFIC and GENERAL nouns were seen to differ in the N400 and N700 time-windows, with SPECIFIC words yielding more negative-going waves than GENERAL nouns in both windows. Effects were present, albeit in a smaller time-window, even for a subset of the stimuli matched in imageability, indicating that something else other than imageability drives the effect. Following the overall prediction of Paper IV, this could be related to the assumption that GENERAL nouns would be expected to have more lexical associates. The fact that GENERAL nouns are used to refer back to SPECIFIC nouns in discourse, but not *vice versa*, would be in line with the idea that they are associated with a larger number of words. The fact that significant N400 differences were present in the LD task for the GENERAL-SPECIFIC comparison, but not the GENERAL-ABSTRACT comparison indicates that GENERAL nouns are processed more similarly to ABSTRACT nouns. At the same time, GENERAL nouns are in many cases rated as highly imageable and conceived of as being concrete. Thus, generality might be an overlooked factor modulating concreteness, not captured by definitions of concrete words focusing on sensory content only.

An overall contribution of the present thesis is that it brings together assumptions from linguistic and neurocognitive models of word meaning, in order to shed more light on the semantic representations of nouns differing in concreteness. It highlights the fact that there is an overlap as well as differences in research questions and theoretical modelling used by the two fields to account for the processing of word meaning.

4.2 Additional observations

The present thesis took its departure from the traditional dichotomy of abstract and concrete nouns, first extending it into a three-way distinction between concrete, abstract and emotional nouns in Paper I, following e.g. Altarriba & Bauer (2004).

Based on the observation that level of specificity was important in the word descriptions in Paper I, the concrete category was subsequently further subdivided in Papers III and IV, resulting in the four categories of SPECIFIC, GENERAL, EMOTIONAL and ABSTRACT nouns. The cognitive psychological meaning parameters involved (imageability and emotional arousal) logically allow the possibility of distinguishing four semantic categories by varying the parameter values: high imageability/low arousal (which roughly corresponds to the concrete category in Paper I and SPECIFIC / GENERAL in Papers III-IV) low imageability/low arousal (ABSTRACT nouns in all of the studies), low imageability/high arousal (EMOTIONAL nouns in all of the studies) and, finally, high imageability/high arousal. The last category would correspond to emotionally arousing concrete words such as *bomb*, *blood, scorpion*, *gold medal*, *champagne, sunshine*, which were not tested in the present designs. Another alternative approach to distinguishing and comparing discrete meaning categories would be to continuously vary the parameters of imageability and emotional arousal.

4.3 Challenges and limitations

One major challenge in the experiment design was working without an extensive psycholinguistic database. Since no large-scale collection of word ratings based on psycholinguistic meaning parameters is available for Swedish, word ratings had to be collected for each of the studies in the present thesis. This was possible to do to some extent. However, for time reasons, it could not be done for large stimuli sets. In order to be able to choose and match stimuli based on several different meaning properties, a large set of words, ideally organised in an easily accessible way, would be required.

There were also some properties of the stimuli posing challenges for experiment design. For example, ABSTRACT and GENERAL words were generally more frequent (at least in the Stockholm-Umeå Corpus (Ejerhed et al., 1992) where frequencies were obtained). This pattern would also be expected given their potential to be used in more diverse contexts. The SPECIFIC category included a number of nouns most closely corresponding to the basic level assumed by (Rosch, 1999), such as *fågel* 'bird', *boll* 'ball' and *flygplan* 'airplane'. In order to capture effects of features related to specific colours and shapes, it might have been more optimal to focus exclusively on even more specific, subordinate level words such as *fiskmås* 'seagull' *basketboll* 'basketball' and *jumbojet* 'jumbo jet'. However, this was problematic for form-based reasons, since it tended to skew the stimuli list towards including many long compound words, difficult to match with the GENERAL stimuli. Some SPECIFIC words were suitable in terms of their sensory properties as well as word structure and length, but were instead very infrequent (and possibly also unfamiliar), making them difficult to match with the GENERAL, high frequency words.

Investigating the processing of single words in tasks such as the ones used in the present thesis are likely not to favour ABSTRACT words. In particular, the relatively fast presentation rates and tasks requiring decisions on semantic content for single words in psycho- and neurolinguistic experiments is likely to aggravate processes involved in the construal of abstract word meaning, e.g. meaning related to their use in different contexts might not have time to come into play. Thus, the processing of abstract words in these cases may remain on a relatively superficial level. This problem should be addressed in future studies using other methods, possibly taking into account abstract words' use in context, e.g. spoken language, text, or perhaps in more direct communication such as dialogues. Some suggestions are made in 5.2.1.

4.4 Main conclusions

Puzzling together the pieces found in the results of Papers I, III and IV regarding the relation of the meaning categories under investigation and differences in neural activity, the implications for research on word semantics in each paper can be narrowed down. Paper I suggests that visual information is important for accounting for concrete (specific) noun meaning, since parts of their semantic representations become inaccessible if access to this information is disturbed by lesions to left occipital cortex. The method does not allow for determining if such visual information consists of more high-level mental images or colour and shape-based semantic features. It could, however, be speculated that more low-level type of visual information would be involved, given the lesion localisation in primary sensory cortex, indicating an impairment due to disturbance of access to visual semantic features (as is proposed in Paper I). Emotional and abstract word meanings were spared, indicating that the left occipital lobe is not equally critical for their processing.

Targeting possible hemispheric differences in the processing of words differing in concreteness, Paper III set up the hypothesis that SPECIFIC nouns would yield more RH activation as compared to GENERAL nouns. This prediction was made based on the assumption that SPECIFIC nouns are more associated with visual images, suggested in previous research to activate the RH to a larger degree (Laeng et al., 2003; Paivio, 1990). This hypothesis was not confirmed, interpreted in Paper III to be because of possible differences in the processing of global and local features of images, with the LH favouring local features (which could be expected to be more important for SPECIFIC noun meaning representations) and the RH favouring global features (which could be expected to be more important for GENERAL noun semantic representations (Fink et al., 1996). In line with this, the prediction that SPECIFIC nouns would yield more RH activation is actually counterintuitive also given the result of Paper I, where concrete nouns at specific levels were selectively disturbed by LH lesions. This would rather implicate the LH, and occipital regions in particular, as crucial for the processing of SPECIFIC nouns.

Paper III also tested EMOTIONAL and ABSTRACT nouns, with EMOTIONAL nouns showing relatively faster RTs when presented in the left ear, consistent with the results of previous studies showing greater RH involvement in emotional word processing, at least in tasks involving slow/attentional processing (Abbassi et al., 2015).

Paper IV showed differences in the N400 component between all noun categories (SPECIFIC, GENERAL, EMOTIONAL, ABSTRACT) and PSEUDOWORDS.

ABSTRACT nouns yielded relatively long response times in all tasks in Papers III and IV, in line with a general concreteness effect (faster responses to concrete words). However, in line with other studies, the ABSTRACT category was negatively defined, making it difficult to make precise predictions about it. The results showing that ABSTRACT nouns a) were not impaired by occipital lesions and b) had long response times for left-ear/RH presentation are somewhat consistent with (or at least not speaking against) previous research suggesting that LH regions involved in language processing are particularly important for abstract words. Following the prediction that many associated lexical items lead to small N400s, the low N400 amplitudes seen for ABSTRACT nouns in Paper IV are compatible with the view of Crutch et al. (2009) and Crutch & Warrington (Crutch & Warrington, 2005) that abstract words are organised cognitively based on associative semantic relations. It is also interesting to relate the results to the analysis of shell nouns by Schmid (2000), showing that this type of abstract nouns are often accompanied by subordinate clauses where their meaning content is “unpacked”. Overall, the noun category which still remains the least well understood is that of ABSTRACT nouns.

5. Future directions

In the following sections, some questions to pursue in further research are outlined.

5.1 Swedish psycholinguistic database

As suggested in Paper II and further discussed in section 4.3 of this thesis, there is a great need for a Swedish psycholinguistic database similar to e.g. the English MRC database (Coltheart, 1981) and the Norwegian database Ordforrådet (Lind, Simonsen, Hansen, Holm & Mevik, 2013; Simonsen et al., 2013). A larger database could be constructed using a method similar to the one described in Paper II via a web-based interface. Word rating data for several word properties, among them imageability, concreteness, emotional arousal/valence, AoA, familiarity, meaningfulness, conceptual features etc. could be collected for a large number of words and organised in a common database together with other relevant word properties. These could include written and oral frequencies, bigram and trigram frequencies, measurements of phonological neighbourhood and other useful measures. Efforts should be made to gather already available resources that other researchers may have collected for Swedish words. The corpus should ideally be tagged for parts of speech. A rating scale for estimating word specificity could also be developed.

A project focused on Swedish word ratings could also be extended to include alternative approaches to quantifying lexical semantic properties, complementary to subjective word ratings, such as extrapolating values from human word ratings using semantic space models (Landauer, 2007; Roll et al., 2012; Westbury et al., 2013).

5.2 Developing modelling of word meanings

5.2.1 Modelling the semantic structures of abstract words

As noted above, in the studies carried out within the present thesis, the abstract word category has largely been defined by its lack of certain types of more “concrete” semantic content (sensory, emotional), along the same lines as the definitions used in many other studies. Given the limited conclusions that could be drawn about abstract words, the study of semantic structures related to abstract words is a well-needed track to pursue in future work. In the same vein as Crutch et al. (2013) and Wiemer-Hastings & Xu (2005) more fine-grained categories could be distinguished among abstract words based on e.g. conceptual feature ratings, for example words related to social interaction (*friendship*, *jealousy*, *love*), logical reasoning/problem solving (*think*, *compare*, *analyse*). An open question is whether it would be possible to distinguish fine-grained subcategories of abstract words suitable for creating stimuli sets that could be tested in psycho- and neurolinguistic experiments.

In order to distance oneself from the negative definition of abstract nouns (having fewer semantic features etc), it would probably be helpful to focus more on studying what can be seen as the more specific characteristics of abstract words. One such characteristic, advocated by Schmid (2000) based on corpus work, arguably is abstract nouns' capacity to function as pointers to more detailed or complex information, in the case of 'shell nouns' (e.g. *fact*, *idea*, *problem*), information provided in surrounding clauses. This capacity could account for the prominent use of shell nouns in the structuring of discourse. In the case of other nouns referring to abstract phenomena (e.g. *religion*), experiences (e.g. *education*), and situations (e.g. *accident*) they might activate larger meaning structures such as semantic frames (Fillmore, 1976, 1985; Mårtensson et al., 2011), involving concrete as well as abstract objects and scenarios. Pursuing this research, abstract noun meanings could be more extensively studied in texts, spoken discourse and dialogues.

5.2.2 Further coding of word description data

As is briefly mentioned in Paper I (p. 7), word descriptions were originally gathered for ABSTRACT and EMOTIONAL words as well as for CONCRETE words, but given the characteristics of the case study, the decision was made to focus on a more exhaustive analysis of the sensory-related words in the CONCRETE word descriptions for Paper I. Part of the EMOTIONAL and ABSTRACT word descriptions served as a control, confirming ZZ's difficulties with CONCRETE words and preservation of ABSTRACT/EMOTIONAL word meaning processing.

However, at an early stage of data analysis, attempts were made to code the data in order to analyse other aspects of their semantic content. One of these concerned the degree to which personal vs. general[9] information was expressed in the

[9] The term 'general' here should not be confused with the GENERAL word category, here it rather refers to word-related information belonging to a general definition rather than personal experiences or evaluations.

participants' word descriptions. For example, when given a test word (e.g. *parrot*), in addition to general information such as "*a colourful bird with a big beak that talks*" participants quite often produced utterances like: "*my friend has one at home*" or "*I like them very much*" etc. An analysis of the distinction between general and personal information might be particularly informative in the interpretation of the ABSTRACT and EMOTIONAL word descriptions. The use of personal and general information might also vary in the structuring of semantic information in discourse produced by clinical and healthy populations. However, partly due to the focus on concrete word descriptions in Paper I and partly due to difficulties segmenting the data into relevant units for capturing the expression of personal/general information, no such analysis was carried out at that point in time. A possible solution could be to use intonation units (Chafe, 1988). This type of unit has for example been used by Holsanova (2008) for segmentation of data in audio description (i.e. verbal descriptions of visual scenes for visually impaired audiences), a material which can be expected to share some properties with the free oral word descriptions. Furthermore, the notions of 'connotation' and 'denotation' might be helpful in creating criteria for coding personal and general information.

5.2.3 Levels of specificity with novel words

As described in 4.3, there are some limitations in stimuli design as regards the properties of nouns at different levels of semantic specificity. For example, specific nouns corresponding to subordinate levels of categorisation are often low-frequency compound words, basic level nouns are often short, early acquired and have intermediate frequency and general nouns at superordinate levels of categorisation are highly frequent and relatively short. One possible way to get around this problem might be to design an experiment where participants learn novel words at different levels of specificity matched for these variables. Adapting a procedure previously used with toddlers (Borgström, Koss Torkildsen, & Lindgren, 2015; Torkildsen et al., 2009), pseudowords could be matched with pictures of novel objects with different degree of specificity, which could then be trained in a group of healthy, adult participants before comparing their processing behaviourally and with ERP's.

5.2.4 Other content word classes

In the present thesis, the main focus was on nouns. In order to control for possible word class effects, the stimuli used in the four studies were all nouns. However, in Paper I, where the participants' free oral production was analysed, some words from other word classes (e.g. adjectives and verbs) were also included among the words analysed based on their meaning components related to different sensory modalities. There is nothing in the theoretical framework outlined in the present thesis that would necessarily limit it to nouns only. Similar predictions could be made for other word classes. For example, specific, general, emotional and abstract adjectives (such as *purple, colour, angry, rational*) or verbs (*swim*, *move*, *love*, *think*) can be expected to follow patterns similar to those observed in the studies reported on here.

Abstract and concrete verbs have previously been compared (Rodríguez-Ferreiro, Gennari, Davies, & Cuetos, 2011). Related to level of semantic specificity, Spunt, Kemmerer & Adolphs (2015) let participants conceptualise actions at what they refer to as different levels of abstraction. The question "how to ride a bike" was assumed to activate representations at lower levels of abstraction such as "grip handle bars", whereas "why" questions would be assumed to activate more abstract levels of representation such as "in order to get exercise".

5.3 Further neuroimaging studies

5.3.1 Localisation

Although the methods used in the present thesis, taken together with previous knowledge, might allow for some speculation about the localisation of neural activation associated with word processing, they cannot provide any direct measure of it. In order for any strong conclusions to be made about the localisation of activity for different word types, other methods have to be used. For instance, relating the performance of neurological patients to Magnetic Resonance Imaging (MRI) data, or using functional Magnetic Resonance Imaging (fMRI) paradigms with healthy participants could shed more light on the localisation of processing associated with different lexical semantic categories. This might also allow for a more fine-grained analysis of concrete nouns which differ in their association with sub-components of visual processing, such as modality-specific features, in the case of visual features, those that are related to colour, shape or location in space. Another approach which could be informative is to use source localisation techniques such as 'Low Resolution Electromagnetic Tomography' (LORETA) (Palmero-Soler & Dolan, 2007) to estimate where the effects contributing to the ERPs are generated.

5.3.2 Earlier ERP components

Paper IV investigated rather late ERP components (N400 and N700), of which at least the N700 has been suggested to be associated with either conscious mental imagery (West & Holcomb, 2000) or reactivation of previous semantic information (Nittono et al., 2002). However, using MEG, Pulvermüller, Shtyrov & Ilmoniemi (2005) found support for early (within 150 ms of word onset) activation of semantic information associated with motor-related verbs (Finnish verbs *hotki* 'eat' and *potki* 'kick'). Evidence indicating that sensory semantic features are processed earlier than the N400 time-window was also found by Pulvermüller, Shtyrov & Hauk (2009) A recent MEG study investigating the time-course and localisation of neural activation for words continuously varying in imageability (Lewis & Poeppel, 2014) found that early occipital activation (100-300 ms time-window) correlated with word imageability. Thus, looking at early components using MEG or EEG could possibly shed more light on the processing of words with different degrees of specificity.

References

Abbassi, E., Blanchette, I., Ansaldo, A. I., Ghassemzadeh, H., & Joanette, Y. (2015). Emotional words can be embodied or disembodied: the role of superficial vs. deep types of processing. *Frontiers in Psychology*, *6*. http://doi.org/10.3389/fpsyg.2015.00975

Ahlsén, E. (2006). *Introduction to Neurolinguistics*. John Benjamins Publishing.

Aktas, R. N., & Cortes, V. (2008). Shell nouns as cohesive devices in published and ESL student writing. *Journal of English for Academic Purposes*.

Allwood, J. (1999). *The Swedish Spoken Language Corpus at Göteborg University*. In *Proceedings of Fonetik 99*, Gothenburg Papers in Theoretical Linguistics 81, University of Göteborg, Dept of Linguistics.

Altarriba, J., & Bauer, L. M. (2004). The Distinctiveness of Emotion Concepts: A Comparison between Emotion, Abstract, and Concrete Words. *The American Journal of Psychology 117*(3), 389–410. http://doi.org/10.2307/4149007?ref=search-gateway:bd3842d369b0804ee26398547cb3e54d

Altarriba, J., Bauer, L. M., & Benvenuto, C. (1999). Concreteness, context availability, and imageability ratings and word associations for abstract, concrete, and emotion words. *Behavior Research Methods*, *31*(4), 578–602.

Ariel, M. 1990. *Accessing noun-phrase antecedents*. London: Routledge.

Barber, H. A., Otten, L. J., Kousta, S.-T., & Vigliocco, G. (2013). Concreteness in word processing: ERP and behavioral effects in a lexical decision task. *Brain and Language*, *125*(1), 47–53. http://doi.org/10.1016/j.bandl.2013.01.005

Barsalou, L. W. (1999). Perceptual symbol systems. *Behavioral and Brain Sciences*, *22*(4), 577–660.

Barsalou, L. W., & Wiemer-Hastings, K. (2005). Situating abstract concepts. In *Grounding Cognition: The Role of Perception and Action in Memory, Language, and Thought*. Eds. D. Pecher and R. Zwaan. New York, NY: Cambridge University Press), 129–163. doi: 10.1017/CBO9780511499968.007

Bednarek, M. A. (2005). Frames revisited—the coherence-inducing function of frames. *Journal of Pragmatics 37*, 685-705.

Binder, J. R., Westbury, C., McKiernan, K. A., Possing, E. T., & Medler, D. A. (2005). Distinct brain systems for processing concrete and abstract concepts. *Journal of Cognitive Neuroscience*, *17*(6), 905–917.

Blazhenkova, O., & Kozhevnikov, M. (2009). The new object-spatial-verbal cognitive style model: Theory and measurement. *Applied Cognitive Psychology*, *23*(5), 638–663. http://doi.org/10.1002/acp.1473

Blomberg, F., & Öberg, C. (2015). Swedish and English word ratings of imageability, familiarity and age of acquisition are highly correlated. *Nordic Journal of Linguistics*, *38*(3), 351–364. http://doi.org/10.1017/S0332586515000220

Blomberg, F., Roll, M., Lindgren, M., Brännström, K. J., & Horne, M. (2015). Emotional arousal and lexical specificity modulate response times differently depending on ear of presentation in a dichotic listening task. *The Mental Lexicon*, *10*(2), 221–246. http://doi.org/10.1075/ml.10.2.03blo

Blomberg, F., Roll, M., Lindgren, M., & Horne, M. (manuscript). Lexical specificity, imageability and emotional arousal modulate the N400 and the N700 during imageability rating and lexical decision tasks.

Bolinger, D. (1977). *Pronouns and repeated nouns*. Indiana University Linguistics Club: Indiana.

Borgström, K., Koss Torkildsen, von, J., & Lindgren, M. (2015). Substantial gains in word learning ability between 20 and 24 months: A longitudinal ERP study. *Brain and Language 149* (2015), 33-45.

Borod, J. C., Andelman, F., Obler, L. K., Tweedy, J. R., & Wilkowitz, J. (1992). Right hemisphere specialization for the identification of emotional words and sentences: Evidence from stroke patients. *Neuropsychologia*, *30*(9), 827–844. http://doi.org/10.1016/0028-3932(92)90086-2

Boulenger, V., Mechtouff, L., Thobois, S., Broussolle, E., Jeannerod, M., & Nazir, T. A. (2008). Word processing in Parkinson's disease is impaired for action verbs but not for concrete nouns. *Neuropsychologia*, *46*(2), 743–756. http://doi.org/10.1016/j.neuropsychologia.2007.10.007

Breedin, S. D., Saffran, E. M., & Coslett, H. B. (1994). Reversal of the concreteness effect in a patient with semantic dementia. *Cognitive Neuropsychology*, *11*(6), 617–660. http://doi.org/10.1080/02643299408251987

Broca, P. (1861). {Remarque sur le siege de la facult\\'{e} du language articul\\'{e}, suivie d\'une observation d\‘aph\\’{e}mie (perte de la parole)}. *{Bulletin De La Soci\\“{E}T\\”{E} Anatomique De Paris}*, *36*, 330–356.

Buchanan, T. W., Lutz, K., Mirzazade, S., Specht, K., Shah, N. J., Zilles, K., & Jäncke, L. (2000). Recognition of emotional prosody and verbal components of spoken language: an fMRI study. *Cognitive Brain Research*, *9*(3), 227–238. http://doi.org/10.1016/S0926-6410(99)00060-9

Caramazza, A. (1998). The Interpretation of Semantic Category-specific Deficits: What Do They Reveal About the Organization of Conceptual Knowledge in the Brain? *Neurocase*, *4*(4-5), 265–272. http://doi.org/10.1080/13554799808410627

Caramazza, A. (1984). The logic of neuropsychological research and the problem of patient classification in aphasia. *Brain and Language 21*, 9–20. Retrieved from http://www.sciencedirect.com/science/article/pii/0093934X84900324

Chafe, W. (1988). Clause Combining in Grammar and Discourse - Google Books. *Clause Combining in Grammar and Discourse*.

Citron, F. M. M. (2012). Neural correlates of written emotion word processing: A review of recent electrophysiological and hemodynamic neuroimaging studies. *Brain and Language*, *122*(3), 211–226. http://doi.org/10.1016/j.bandl.2011.12.007

Coltheart, M. (1981). The MRC psycholinguistic database. *The Quarterly Journal of Experimental Psychology Section A*, *33*(4), 497–505. http://doi.org/10.1080/14640748108400805

Cortese, M. J., & Khanna, M. M. (2008). Age of acquisition ratings for 3,000 monosyllabic words. *Behavior Research Methods*, *40*(3), 791–794. http://doi.org/10.3758/BRM.40.3.791

Crutch, S. J., & Warrington, E. K. (2003). Preservation of Propositional Speech in a Pure Anomic: The Importance of an Abstract Vocabulary. *Neurocase*, *9*(6), 465–481. http://doi.org/10.1076/neur.9.6.465.29373

Crutch, S. J., & Warrington, E. K. (2005). Abstract and concrete concepts have structurally different representational frameworks. *Brain*, *128*(3), 615–627. http://doi.org/10.1093/brain/awh349

Crutch, S. J., & Warrington, E. K. (2008). Contrasting patterns of comprehension for superordinate, basic-level, and subordinate names in semantic dementia and aphasic stroke patients. *Cognitive Neuropsychology*, *25*(4), 582–600. http://doi.org/10.1080/02643290701862290

Crutch, S. J., Connell, S., & Warrington, E. K. (2009). The different representational frameworks underpinning abstract and concrete knowledge: Evidence from odd-one-out judgements. *The Quarterly Journal of Experimental Psychology*, *62*(7), 1377–1390. http://doi.org/10.1080/17470210802483834

Crutch, S. J., Troche, J., Reilly, J., & Ridgway, G. R. (2013). Abstract conceptual feature ratings: the role of emotion, magnitude, and other cognitive domains in the organization of abstract conceptual knowledge. *Frontiers in Human Neuroscience*, *7*. http://doi.org/10.3389/fnhum.2013.00186/abstract

Crutch, S. J., Williams, P., Ridgway, G. R., & Borgenicht, L. (2012). The role of polarity in antonym and synonym conceptual knowledge: Evidence from stroke aphasia and multidimensional ratings of abstract words. *Neuropsychologia 50* (2012), 2636-2644.

Ejerhed E., Källgren G., Wennstedt O. & Åström M. (1992). The linguistic annotation system of the Stockholm-Umeå Corpus project. *Tech Rep 33*, Department of General Linguistics, Umeå University, Umeå, Sweden.

Ely, P. W., Graves, R. E., & Potter, S. M. (1989). Dichotic listening indices of right hemisphere semantic processing. *Neuropsychologia*, *27*(7), 1007–1015. http://doi.org/10.1016/0028-3932(89)90076-6

Fiebach, C. J., & Friederici, A. D. (2004). Processing concrete words: fMRI evidence against a specific right-hemisphere involvement. *Neuropsychologia*.

Fillmore C. J. (1985). *Frames and the semantics of understanding*. Quaderni di Semantica 6: 222–254.

Fillmore, C. J. (1976). Frame Semantics and the Nature of Language. *Annals of the New York Academy of Sciences*, *280*(1 Origins and E), 20–32. http://doi.org/10.1111/j.1749-6632.1976.tb25467.x

Fink, G. R., Halligan, P. W., Marshall, J. C., Frith, C. D., Frackowiak, R. S. J., & Dolan, R. J. (1996). Where in the brain does visual attention select the forest and the trees? *Nature*, *382*(6592), 626–628. http://doi.org/10.1038/382626a0

Fodor, J. (1983). *The modularity of mind: an essay on faculty psychology*. Cambridge: MIT Press.

Forde, E. M. E., Francis, D., Riddoch, M. J., & Humphreys, G. W. (1997). On the Links between Visual Knowledge and Naming: a Single Case Study of a Patient with a Category-specific Impairment for Living Things. *Cognitive Neuropsychology*, *14*(3), 403–458. http://doi.org/10.1080/026432997381538

Fortescue, M. (2009). *A Neural Network Model of Lexical Organisation*. London/New York: Continuum.

Fortescue, M. (2010). A neural network approach to compositionality and co-compositionality. *The Mental Lexicon*, *5*(2), 180–204. http://doi.org/10.1075/ml.5.2.03for

Frege, G. (1984). On sense and reference. In McGuiness (ed.) *Gottlob Frege: Collected Papers on Mathematics, Logic, and Philosophy*, pp. 157-177. Oxford: Basil Blackwell. Original work published 1892 as Über Sinn und Bedeutung, *Zeitschrift für Philosophie und Philosophishe Kritik*: p. 25-50.

Friedmann, N. (2013). A selective deficit in imageable concepts: a window to the organization of the conceptual system, *Frontiers in Human Neuroscience 7*(226), 1–13. http://doi.org/10.3389/fnhum.2013.00226/abstract

Fuster, J. M. (2009). Cortex and memory: emergence of a new paradigm. *Journal of Cognitive Neuroscience*, *21*(11), 2047–2072.

Gainotti, G. (2004). A metanalysis of impaired and spared naming for different categories of knowledge in patients with a visuo-verbal disconnection. *Neuropsychologia*, *42*(3), 299–319. http://doi.org/10.1016/j.neuropsychologia.2003.08.006

González, J., Barros-Loscertales, A., & Pulvermüller, F. (2006). Reading cinnamon activates olfactory brain regions. *NeuroImage 32*(2006), 906-912.

Goodglass, H., Hyde, M. R., & Blumstein, S. (1969). Frequency, Picturability and Availability of Nouns in Aphasia. *Cortex*, *5*(2), 104–119. http://doi.org/10.1016/S0010-9452(69)80022-5

Gullick, M. M., Mitra, P., & Coch, D. (2013). Imagining the truth and the moon: An electrophysiological study of abstract and concrete word processing. *Psychophysiology*, *50*(5), 431–440. http://doi.org/10.1111/psyp.12033

Halliday, M. A. K. & Hasan, R. (1976). *Cohesion in English*. London: Longman.

Hauk, O., Johnsrude, I., & Pulvermüller, F. (2004). Somatotopic Representation of Action Words in Human Motor and Premotor Cortex. *Neuron, 41*, 301-307.

Hoffman, P. (2015). The meaning of "life" and other abstract words: Insights from neuropsychology. *Journal of Neuropsychology*, n/a–n/a. http://doi.org/10.1111/jnp.12065

Holsanova, J. (2008). Discourse, vision, and cognition. In *Human Cognitive Processing 23*, 1387-6724. John Benjamins Publishing Company: Amsterdam/Philadelphia.

Huang, H.-W., Lee, C.-L., & Federmeier, K. D. (2010). Imagine that! ERPs provide evidence for distinct hemispheric contributions to the processing of concrete and abstract concepts. *NeuroImage*, *49*(1), 1116–1123. http://doi.org/10.1016/j.neuroimage.2009.07.031

Hugdahl, K. (2000). Lateralization of cognitive processes in the brain. *Acta Psychologica*, *105*(2-3), 211–235. http://doi.org/10.1016/S0001-6918(00)00062-7

Hugdahl, K. (2009). Left temporal lobe structural and functional abnormality underlying auditory hallucinations. *Frontiers in Neuroscience*, *3*(1). http://doi.org/10.3389/neuro.01.001.2009

Ivanič, R. (1991). Nouns in search of a context: A study of nouns with both open- and closed-system characteristics. *IRAL - International Review of Applied Linguistics in Language Teaching*, *29*(2), 93-114. http://doi.org/10.1515/iral.1991.29.2.93

Jackson, H. (2013). *Lexicography – An Introduction*. Routledge: London.

Jefferies, E., Patterson, K., Jones, R. W., & Lambon Ralph, M. A. (2009). Comprehension of concrete and abstract words in semantic dementia. *Neuropsychology*, *23*(4), 492–499. http://doi.org/10.1037/a0015452

Johnson, K. E., & Mervis, C. B. (1997). Effects of varying levels of expertise on the basic level of categorization. *Journal of Experimental Psychology: General*, *126*(3), 248–277. http://doi.org/10.1037/0096-3445.126.3.248

Kadesh, I., Riese, M., & Anisfeld, M. (1976). Dichotic listening in the study of semantic relations. *Journal of Verbal Learning and Verbal Behavior*, *15*(2), 213–225. http://doi.org/10.1016/0022-5371(76)90020-7

Kanske, P., & Kotz, S. A. (2007). Concreteness in emotional words: ERP evidence from a hemifield study. *Brain Research*, *1148*, 138–148. http://doi.org/10.1016/j.brainres.2007.02.044

Kemmerer, D. (2014). *Cognitive Neuroscience of Language*. Psychology Press.

Kensinger, E. A., & Schacter, D. L. (2006). Processing emotional pictures and words: Effects of valence and arousal. *Cognitive, Affective, & Behavioral Neuroscience 6* (2), 110-126.

Kosslyn, S. M., Ganis, G., & Thompson, W. L. (2001). Neural foundations of imagery. *Nature Reviews Neuroscience*, *2*(9), 635–642. http://doi.org/10.1038/35090055

Kounios, J., & Holcomb, P. J. (1994). Concreteness effects in semantic processing: ERP evidence supporting dual-coding theory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *20*(4), 804–823. http://doi.org/10.1037/0278-7393.20.4.804

Kousta, S.-T., Vigliocco, G., Vinson, D. P., Andrews, M., & Del Campo, E. (2011). The representation of abstract words: Why emotion matters. *Journal of Experimental Psychology: General*, *140*(1), 14–34. http://doi.org/10.1037/a0021446

Kousta, S.-T., Vinson, D. P., & Vigliocco, G. (2009). Emotion words, regardless of polarity, have a processing advantage over neutral words. *Cognition*, *112*(3), 473–481. http://doi.org/10.1016/j.cognition.2009.06.007

Kroll, J. F., & Merves, J. S. (1986). Lexical access for concrete and abstract words. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *12*(1), 92. http://doi.org/10.1037/0278-7393.12.1.92

Kutas, M., & Federmeier, K. D. (2011). Thirty Years and Counting: Finding Meaning in the N400 Component of the Event-Related Brain Potential (ERP). *Annual Review of Psychology*, *62*(1), 621–647. http://doi.org/10.1146/annurev.psych.093008.131123

Kutas, M., & Hillyard, S. A. (1980). Reading senseless sentences: Brain potentials reflect semantic incongruity. *Science 207* (4427), 203-205.

Laeng, B., Zarrinpar, A., & Kosslyn, S. M. (2003). Do separate processes identify objects as exemplars versus members of basic-level categories? Evidence from hemispheric specialization. *Brain and Cognition*, *53*(1), 15–27. http://doi.org/10.1016/S0278-2626(03)00184-2

Lakoff, G., & Johnson, M. (1980). *Metaphors we Live by*. Chicago and London: Chicago University Press.

Lakoff G. (1987). *Women, Fire and Dangerous Things: What Categories Reveal about the Mind*. Chicago and London: Chicago University Press.

Landauer K, McNamara DS, Dennis S, and Kintsch W. (2007). (Eds), *Handbook of Latent Semantic Analysis*. Mahwah, NJ: Lawrence Erlbaum.

Langacker, R. W. (1990). *Concept, Image and Symbol: The Cognitive Basis of Meaning*. Berlin/New York: Mouton de Gruyter.

Lau, E. F., Phillips, C., & Poeppel, D. (2008). A cortical network for semantics: (de)constructing the N400. *Nature Reviews Neuroscience*, *9*(12), 920–933. http://doi.org/10.1038/nrn2532

Lewis, G., & Poeppel, D. (2014). The role of visual representations during the lexical access of spoken words. *Brain and Language 134*, 1-10.

Lind, M., Simonsen, H.G., Hansen, P., Holm, E. & Mevik, B.-H. (2013). "Ordforrådet" – en leksikalsk database over et utvalg norske ord. *Norsk tidsskrift for logopedi 59*(1), 18-26.

Luck, S. J. (2014). *An Introduction to the Event-Related Potential Technique*. MIT Press.

Luzzatti, C., Rumiati, R. I., & Ghirardi, G. (1998). A functional model of visuo-verbal disconnection and the neuroanatomical constraints of optic aphasia. *Neurocase*, *4*(1), 71–87. http://doi.org/10.1080/13554799808410609

Lynott, D., & Connell, L. (2012). Modality exclusivity norms for 400 nouns: The relationship between perceptual experience and surface word form. *Behavior Research Methods*, *45*(2), 516–526. http://doi.org/10.3758/s13428-012-0267-0

Lyons, J. (1977). *Semantics,* 2 vols. Cambridge: Cambridge University Press.

Manning, L. (2000). Loss of visual imagery and defective recognition of parts of wholes in optic aphasia. *Neurocase*, *6*(2), 111–128. http://doi.org/10.1080/13554790008402765

Mårtensson, F., Roll, M., Apt, P., & Horne, M. (2011). Modeling the meaning of words: Neural correlates of abstract and concrete noun processing. *Acta Neurobiologiae Experimentalis 71*, 455-478.

Mårtensson, F., Roll, M., Lindgren, M., Apt, P., & Horne, M. (2013). Sensory-specific anomic aphasia following left occipital lesions: Data from free oral descriptions of concrete word meanings. *Neurocase*, *20*(2), 192–207. http://doi.org/10.1080/13554794.2012.741258

Mervis, C. B., & Crisafi, M. A. (1982). Order of Acquisition of Subordinate-, Basic-, and Superordinate-Level Categories. *Child Development*, *53*(1), 258–266. http://doi.org/10.2307/1129660?ref=search-gateway:b77eab3277bcaf4ef51d71a6c85023d0

Miller, G. A., & Fellbaum, C. (1991). Semantic networks of English. *Cognition 41*, 197-229.

Miller, G. A., Beckwith, R., Fellbaum, C., Gross, D., & Miller, K. J. (1990). Introduction to WordNet: An On-line Lexical Database *. *International Journal of Lexicography*, *3*(4), 235–244. http://doi.org/10.1093/ijl/3.4.235

Moseley, R. L., Shtyrov, Y., Mohr, B., Lombardo, M. V., Baron-Cohen, S., & Pulvermüller, F. (2015). Lost for emotion words: What motor and limbic brain activity reveals about autism and semantic theory. *NeuroImage*, *104*(C), 413–422. http://doi.org/10.1016/j.neuroimage.2014.09.046

Navon, D. (1977). Forest before trees: The precedence of global features in visual perception. *Cognitive Psychology*, *9*(3), 353–383. http://doi.org/10.1016/0010-0285(77)90012-3

Nittono, H., Suehiro, M., & Hori, T. (2002). Word imageability and N400 in an incidental memory paradigm. *International Journal of Psychophysiology*, 44(2002), 219-229.

Paivio, A. (1978). A dual coding approach to perception and cognition. In HD Pick & E. Saltzman (Eds). *Modes of perceiving and processing information*, 39-51.

Paivio, A. (1990). *Mental Representations*. Oxford Psychology Series.

Paivio, A. (2010). Dual coding theory and the mental lexicon. *The Mental Lexicon*, *5*(2), 205–230. http://doi.org/10.1075/ml.5.2.04pai

Paivio, A., Yuille, J. C., & Madigan, S. A. (1968). Concreteness, imagery, and meaningfulness values for 925 nouns. *Journal of Experimental Psychology*, *76*(1, Pt.2), 1–25. http://doi.org/10.1037/h0025327

Paivio, A., Yuille, J. C., & Rogers, T. B. (1969). Noun imagery and meaningfulness in free and serial recall. *Journal of Experimental Psychology*, *79*(3, Pt.1), 509–514. http://doi.org/10.1037/h0026930

Palazova, M. (2012). *The Functional Locus of Emotion Effects in Visual Word Processing*. Doctoral Dissertation, Humboldt Universität. Berlin.

Palazova, M., Mantwill, K., Sommer, W., & Schacht, A. (2011). Are effects of emotion in single words non-lexical? Evidence from event-related brain potentials. *Neuropsychologia 49,* 2766-2775.

Palmero-Soler, E., Dolan, K., Hadamschek, V., & Tass, P. A. (2007). swLORETA: A novel approach to robust source localization and synchronization tomography. *Physics in Medicine & Biology*, 52, 1783–1800.

Papagno, C., Capasso, R., & Miceli, G. (2009). Reversed concreteness effect for nouns in a subject with semantic dementia. *Neuropsychologia 47*, 1138-1148.

Patterson, K., Nestor, P. J., & Rogers, T. T. (2007). Where do you know what you know? The representation of semantic knowledge in the human brain. *Nature Reviews Neuroscience*, *8*(12), 976–987. http://doi.org/10.1038/nrn2277

Pobric, G., Ralph, M. L., & Jefferies, E. (2009). The role of the anterior temporal lobes in the comprehension of concrete and abstract words: rTMS evidence. *Cortex 45*, 1104-1110.

Prior, M. R., Cumming, G., & Hendy, J. (1984). Recognition of abstract and concrete words in a dichotic listening paradigm. *Cortex*, *20*(1), 149–157.

Psychology Software Tools, Inc. [E-Prime 2.0]. (2012). Retrieved from http://www.pstnet.com.

Pulvermüller, F. (1999). Words in the brain's language. *Behavioral and Brain Sciences*, *22*, 253–279.

Pulvermüller, F., & Fadiga, L. (2010). Active perception: sensorimotor circuits as a cortical basis for language, *Nature Reviews Neuroscience 11*, 351-360. http://doi.org/10.1038/nrn2811

Pulvermüller, F., Preissl, H., Lutzenberger, W., & Birbaumer, N. (1996). Brain Rhythms of Language: Nouns Versus Verbs. *European Journal of Neuroscience*, *8*(5), 937–941. http://doi.org/10.1111/j.1460-9568.1996.tb01580.x

Pulvermüller, F., Shtyrov, Y., & Hauk, O. (2009). Understanding in an instant: Neurophysiological evidence for mechanistic language circuits in the brain. *Brain and Language*, *110*(2), 81–94. http://doi.org/10.1016/j.bandl.2008.12.001

Pulvermüller, F., Shtyrov, Y., & Ilmoniemi, R. (2005). Brain Signatures of Meaning Access in Action Word Recognition. *Journal of Cognitive Neuroscience 17*(6), 884-892.

Pylyshyn, Z.W. (1980) Computation and cognition: issues in the foundations of cognitive science. *Behav. Brain Sci. 3*, 111–132.

Reilly, J., & Kean, J. (2007). Formal Distinctiveness of High-and Low-Imageability Nouns: Analyses and Theoretical Implications. *Cognitive Science*, *31*(1), 157–168.

Reilly, J., Grossman, M., & McCawley, G. (2006). A reverse concreteness effect in a subject with semantic dementia. *Brain and Language*.

Reilly, J., Westbury, C., Kean, J., & Peelle, J. E. (2012). Arbitrary Symbolism in Natural Language Revisited: When Word Forms Carry Meaning. *PLoS ONE*, *7*(8), e42286. http://doi.org/10.1371/journal.pone.0042286.t005

Rodríguez-Ferreiro, J., Gennari, S. P., Davies, R., & Cuetos, F. (2011). Neural correlates of abstract verb processing. *Journal of Cognitive Neuroscience*, *23*(1), 106–118.

Rogers, T. T., & Patterson, K. (2007). Object categorization: Reversals and explanations of the basic-level advantage. *Journal of Experimental Psychology: General*, *136*(3), 451–469. http://doi.org/10.1037/0096-3445.136.3.451

Roll, M., Mårtensson, F., Sikström, S., Apt, P., Arnling-Bååth, R., & Horne, M. (2012). Atypical associations to abstract words in Broca's aphasia. *Cortex*, *48*(8), 1068–1072. http://doi.org/10.1016/j.cortex.2011.11.009

Rosch, E. (1999). *Principles of categorization*. In Margolis, E. and Laurence, S (eds.) Concepts: Core Readings. Cambridge: MIT Press.

Rosch, E., & Lloyd, B. B. (1978). *Cognition and Categorization*. New Jersey: Lawrence Erlbaum.

Rosch, E., Mervis, C. B., Gray, W. D., Johnson, D. M., & Boyes-Braem, P. (1976). Basic objects in natural categories. *Cognitive Psychology*, *8*(3), 382–439. http://doi.org/10.1016/0010-0285(76)90013-X

Russell, B. (1905). On Denoting. *Mind*, 14(56), 479-493.

Sabsevitz, D. S., Medler, D. A., Seidenberg, M., & Binder, J. R. (2005). Modulation of the semantic system by word imageability. *NeuroImage*, *27*(1), 188–200. http://doi.org/10.1016/j.neuroimage.2005.04.012

Saeed, J. (2009). *Semantics*. Third revised edition. Oxford:Wiley-Blackwell.

San Roque, L., Kendrick, K. H., Norcliffe, E., Brown, P., Defina, R., Dingemanse, M., Dirksmeyer, T., Enfield, N. J., Floyd, S., Hammond, J., Rossi, G., Tufvesson, S., Van Putten, S., & Majid, A. (2015). Vision verbs dominate in conversation across cultures, but the ranking of non-visual verbs varies. *Cognitive Linguistics, 26*, 31-60. doi:10.1515/cog-2014-0089.

Schank R.C. & Abelson, R.P. (1977). *Scripts, Plans, Goals and Understanding: An Inquiry into Human Knowledge Structures*. Lawrence Erlbaum Associates, Hillsdale, NJ.

Schmid, H.-J. (2000). *English Abstract Nouns as Conceptual Shells*. New York: Walter de Gruyter.

Schwanenflugel, P. J., & Shoben, E. J. (1983). Differential context effects in the comprehension of abstract and concrete verbal materials. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *9*(1), 82–102. http://doi.org/10.1037/0278-7393.9.1.82

Schwanenflugel, P. J., Harnishfeger, K. K., & Stowe, R. W. (1988). Context availability and lexical decisions for abstract and concrete words. *Of Memory and Language, 27*(5): 499-520.

Shallice, T., & Cooper, R. P. (2013). Is there a semantic system for abstract words? *Frontiers in Human Neuroscience*. http://dx.doi.org/10.3389/fnhum.2013.00175.

Simonsen, H. G., Lind, M., Hansen, P., Holm, E., & Mevik, B.-H. (2013). Imageability of Norwegian nouns, verbs and adjectives in a cross-linguistic perspective. *Clinical Linguistics & Phonetics 27*, 1–12. http://doi.org/doi: 10.3109/02699206.2012.752527

Spunt, R. P., Kemmerer, D., & Adolphs, R. (2015). The neural basis of conceptualizing the same action at different levels of abstraction. *Social Cognitive and Affective Neuroscience 2015*, 1-11 nsv084. http://doi.org/10.1093/scan/nsv084

Stadthagen-Gonzalez, H., & Davis, C. J. (2006). The Bristol norms for age of acquisition, imageability, and familiarity - Springer. *Behavior Research Methods 38*(4), 598-605.

Swick, D., Ashley, V., & Turken, A. U. (2008). Left inferior frontal gyrus is critical for response inhibition. *BMC Neuroscience*, *9*(1), 1. http://doi.org/10.1186/1471-2202-9-102

Tanaka, J. W., & Taylor, M. (1991). Object categories and expertise: Is the basic level in the eye of the beholder? *Cognitive Psychology*, *23*(3), 457–482.

Thomsen, T., Rimol, L. M., Ersland, L., & Hugdahl, K. (2004). Dichotic listening reveals functional specificity in prefrontal cortex: an fMRI study. *NeuroImage 21*(1), 211-218.

Torkildsen, J. V. K., Friis Hansen, H., Svangstu, J. M., Smith, L., Simonsen, H. G., Moen, I., & Lindgren, M. (2009). Brain dynamics of word familiarization in 20-month-olds: Effects of productive vocabulary size. *Brain and Language*, *108*(2), 73–88. http://doi.org/10.1016/j.bandl.2008.09.005

Trumpp, N. M., Kliese, D., Hoenig, K., Haarmeier, T., & Kiefer, M. (2013). Losing the sound of concepts: Damage to auditory association cortex impairs the processing of sound-related concepts. *Cortex, 49*(2), 474-486.

Tyler, L. K., Moss, H. E., Durrant-Peatfield, M. R., & Levy, J. P. (2000). Conceptual Structure and the Structure of Concepts: A Distributed Account of Category-Specific Deficits. *Brain and Language 75*(2), 195-231.

Ullmann, S. (1962). *Semantics: An Introduction to the Science of Meaning*. Oxford: Basil Blackwell.

Vendler, Z. (1968). *Adjectives and nominalizations*. The Hague: Mouton.

Viberg, Å. (1983). The verbs of perception: a typological study. *Linguistics*, *21*(1), 123-162. http://doi.org/10.1515/ling.1983.21.1.123

Viberg, Å. (2008). Emotion and emotionality as a hidden dimension of lexicon and discourse. *Bilingualism: Language and Cognition*, *11*(02), 189-191. http://doi.org/10.1017/S1366728908003350

Viberg, Å. (2015). Sensation, perception and cognition: Swedish in a typological-contrastive perspective. *Functions of Language*, *22*(1), 96–131. http://doi.org/10.1075/fol.22.1.05vib

Wang, J., Conder, J. A., Blitzer, D. N., & Shinkareva, S. V. (2010). Neural representation of abstract and concrete concepts: A meta-analysis of neuroimaging studies. *Human Brain Mapping*, *31*(10), 1459–1468. http://doi.org/10.1002/hbm.20950

Warrington, E. K., & Shallice, T. (1984). Category specific semantic impairments. *Brain 107*, 829-854.

Watson, T. L. (2013). Implications of holistic face processing in autism and schizophrenia. *Front Psychol*.

Weinreich, U. (1972). *Explorations in Semantic Theory*. The Hague: Mouton.

Welcome, S. E., Paivio, A., McRae, K., & Joanisse, M. F. (2011). An electrophysiological study of task demands on concreteness effects: evidence for dual coding theory. *Experimental Brain Research*, *212*(3), 347–358. http://doi.org/10.1007/s00221-011-2734-8

Wernicke, C. (1874). *Der aphasische Symptomencomplex: eine psychologische Studie auf anatomischer Basis*.

West, W. C., & Holcomb, P. J. (2000). Imaginal, semantic, and surface-level processing of concrete and abstract words: an electrophysiological investigation. *Journal of Cognitive Neuroscience*, *12*(6), 1024–1037.

Westbury, C. F., Shaoul, C., Hollis, G., Smithson, L., Briesemeister, B. B., Hofmann, M. J., & Jacobs, A. M. (2013). Now you see it, now you don't: on emotion, context, and the algorithmic prediction of human imageability judgments, 4(991), 1–13. http://doi.org/10.3389/fpsyg.2013.00991/abstract

Wiemer-Hastings, K., & Xu, X. (2005). Content Differences for Abstract and Concrete Concepts. *Cognitive Science*, *29*(5), 719–736. http://doi.org/10.1207/s15516709cog0000_33

Wiemer-Hastings, K., Krug, J., & Xu, X. (2001). Imagery, context availability, contextual constraint, and abstractness. *Proceedings of the 23rd Annual Conference of the cognitive science society* 1134-1139. Mahway: Lawrence Erlbaum Associates.

Zhang, L., & Pylkkänen, L. (2015). The interplay of composition and concept specificity in the left anterior temporal lobe: An MEG study. *NeuroImage*, *111*(C), 228–240. http://doi.org/10.1016/j.neuroimage.2015.02.028

Appendix I: Word ratings

Swedish word	English word	Imag	ImagRating	Emo	EmoRating
apparat	device	391	4	168	3
art	species	295	3	195	3
arv	heritage	327	3	300	2
avsky	disgust	-	-	550	3
avsky	disgust	382	3	-	-
bakverk	pastry	609	3	227	2
balans	balance	429	4	305	3
behållare	container	532	3	118	3
belöning	reward	453	4	432	3
besvikelse	disappointment	382	3	605	1
beundran	admiration	295	3	-	-
bevis	proof	305	3	-	-
cykel	bicycle	686	3	227	3
dator	computer	677	3	197	2
docka	doll	565	4	214	3
dröm	dream	485	4	468	3
ekorre	squirrel	642	4	232	3
elefant	elephant	616	4	241	3
eufori	euphoria	-	-	550	3
eufori	euphoria	409	3	-	-
extas	ecstasy	-	-	541	3
extas	ecstasy	409	3	-	-
fakta	fact	302	4	268	2
farkost	vehicle	593	4	218	3
fientlighet	hostility	437	4	491	3
flaska	bottle	619	4	155	3
flygplan	airplane	691	3	259	3

frestelse	temptation	391	4	500	3
förpackning	package	529	4	127	3
förslag	suggestion	345	4	232	3
förståelse	understanding	377	4	482	3
förtjusning	delight	459	4	464	3
gröda	crop	518	3	200	3
guld	gold	594	4	309	3
gåta	riddle	455	4	341	3
hammare	hammer	618	4	209	3
hav	sea	606	4	427	3
helvete	hell	519	4	464	3
hjärta	heart	617	4	418	3
husgeråd	cookware	386	3	191	3
hämnd	revenge	429	4	495	3
idé	idea	319	4	414	3
individ	individual	440	4	309	3
innehåll	content	391	4	191	3
insekt	insect	586	4	245	3
instrument	instrument	521	4	286	3
intuition	intuition	-	-	355	3
intuition	intuition	214	3	-	-
iver	eagerness	-	-	486	3
iver	eagerness	414	3	-	-
jeans	jeans	673	3	177	3
karriär	career	418	4	386	3
klocka	clock	614	4	214	3
konst	art	493	4	373	3
krav	demand	264	3	503	2
kärna	kernel	542	4	218	3
leksak	toy	569	4	305	3
likhet	similarity	-	-	241	3
likhet	similarity	341	3	-	-
liknelse	simile	334	4	200	3
låda	box	591	4	118	3
lättnad	relief	432	4	509	2

majs	corn	675	4	191	3
mangel	mangle	582	3	160	2
maskin	machine	575	4	186	3
material	material	490	4	168	3
metall	metal	541	4	182	3
miljö	environment	491	3	368	3
minne	memory	391	4	459	3
missnöje	discontent	377	3	-	-
mord	murder	549	4	536	3
motivation	motivation	-	-	427	3
motivation	motivation	250	3	-	-
olust	boredom	406	4	450	3
olycka	accident	518	4	500	3
organ	organ	576	4	282	3
organism	organism	355	3	232	3
orsak	cause	282	4	264	3
personlighet	personality	405	4	405	3
placering	placement	-	-	223	3
placering	placement	341	3	-	-
plagg	garment	507	4	182	3
plast	plastic	505	3	182	3
plats	place	377	4	214	3
plåga	torment	386	4	509	3
potatis	potato	617	4	191	3
process	process	-	-	250	3
process	process	227	3	-	-
produkt	product	435	4	168	3
pryl	gadget	359	3	153	2
prästkrage	marguerite	618	3	-	-
raseri	fury	462	4	564	3
rit	rite	353	4	355	3
rutin	routine	268	3	-	-
schack	chess	645	4	241	3
skalbagge	beetle	640	4	218	3
skönhet	beauty	513	4	436	3

smycke	jewelery	605	3	227	3
smärta	pain	502	4	532	3
spel	game	521	4	273	3
standard	standard	319	4	195	3
stil	style	416	4	264	2
stolthet	pride	424	4	464	3
system	system	340	4	209	3
tallrik	plate	527	4	132	3
tavla	painting	602	4	259	3
telefon	telephone	655	1	236	3
tema	theme	395	4	173	3
torg	market	583	4	209	3
tortyr	torture	533	4	573	3
upprymdhet	elatedness	368	3	-	-
upptäckt	discovery	401	4	423	3
ursäkt	excuse	310	4	423	3
vanvett	frenzy	450	4	473	3
vrede	wrath	377	4	555	3
våld	violence	591	3	-	-
vänlighet	kindness	438	4	445	3
ångest	anxiety	422	4	614	3
älg	moose	604	4	250	3
öken	desert	664	3	-	-

Data collection word rating is taken from:

1 = Blomberg & Öberg (2015)

2 = Blomberg et al. (2015)

3 = Present thesis (Blomberg 2016)

4 = Transferred from English (MRC Psycholinguistic Database)

Appendix II: Original papers

Paper I

Neurocase, 2013
http://dx.doi.org/10.1080/13554794.2012.741258

Routledge
Taylor & Francis Group

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

F. Mårtensson[1], M. Roll[1], M. Lindgren[2], P. Apt[3], and M. Horne[1]

[1]Department of Linguistics and Phonetics, Lund University, Lund, Sweden
[2]Department of Psychology, Lund University, Lund, Sweden
[3]Skåne University Hospital, Department of Neurology, Malmö, Sweden

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

Address correspondence to F. Mårtensson, Center for Languages and Literature, Department of Linguistics and Phonetics, Lund University, Box 201, S-221 00 Lund, Sweden. (E-mail: frida.martensson@ling.lu.se).
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).

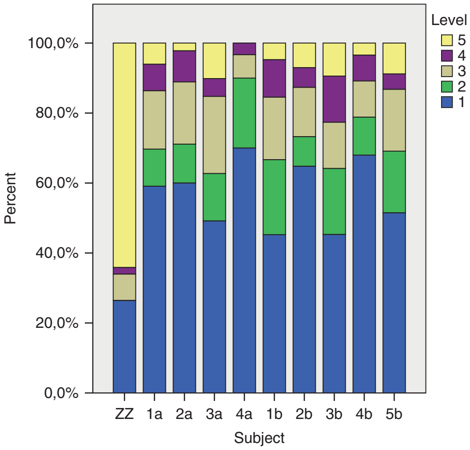


Figure 1a. Distribution of word tokens at different levels of semantic specificity (% of coded words produced by the individual subjects; ZZ = occipital; 1a–4a = aphasic controls; 1b–5b = healthy controls). Level 1 = most specific, level 5 = most general.

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

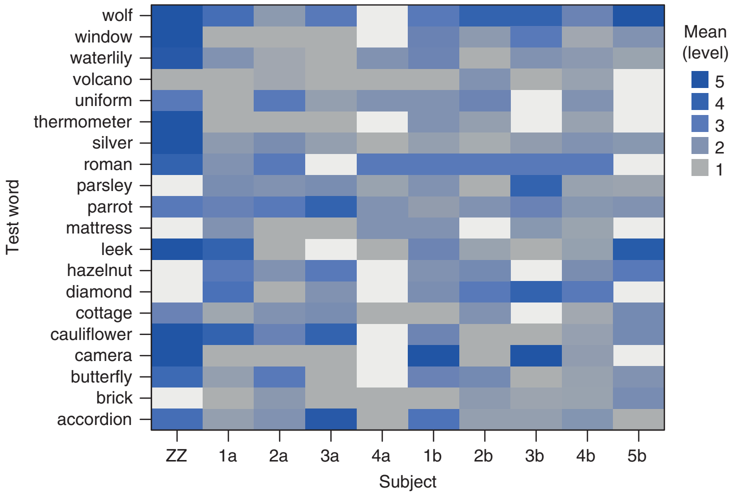


Figure 1b. Heat map showing the distribution of mean levels of semantic specificity associated with words produced in descriptions of each test word for the individual subjects (ZZ = occipital; 1a–4a = aphasic controls; 1b–5b = healthy controls). Level 1 = most specific, level 5 = most general. White 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

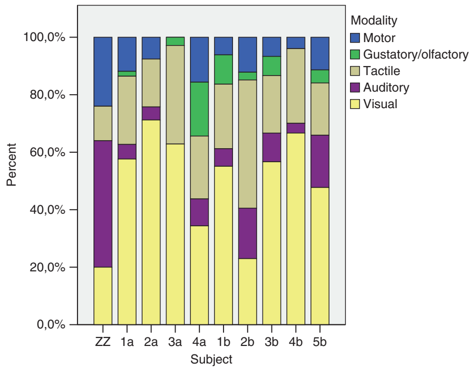


Figure 2. Distribution of sensory and motor meaning components associated with the most specific words produced by individual subjects (ZZ = occipital; 1a–4a = aphasic controls; 1b–5b = healthy controls) expressed as percent of a particular sensory or motor feature in relation to each subjects' total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

REFERENCES

Apt, P. (1997). *Manual till Pia Apts afasiprövning (PAPAP)*. Stockholm: Psykologiförlaget.

Apt, P. (1999). *Svensk benämningsprövning (SBP)*. Malmö: Neurologiska kliniken, Skånes Universitetssjukhus.

Barsalou, L. W., & Wiemer-Hastings, K. (2005). Situating abstract concepts. In D. Pecher & R. A. Swan (Eds.), *Grounding cognition: The role of perception and action in memory, language, and thinking* (pp. 129–163). Cambridge: Cambridge University Press.

Crutch, S. J., & Warrington, E. K. (2003). Preservation of propositional speech in a pure anomic: The importance of an abstract vocabulary. *Neurocase*, *9*, 465–481.

Crutch, S. J., & Warrington, E. K. (2008). Contrasting patterns of comprehension for superordinate, basic level, and subordinate names in semantic dementia and aphasic stroke patients. *Cognitive Neuropsychology*, *25*, 582–600.

Forde, E. M. E., Francis, D., Riddoch, M. J., Rumiati, R. I., & Humphreys, G. W. (1997). On the links between visual knowledge and naming: A single case study of a patient with a category-specific impairment for living things. *Cognitive Neuropsychology*, *14*, 403–458.

Gainotti, G. (2004). A metanalysis of impaired and spared naming for different categories of knowledge in patients with a visuo-verbal disconnection. *Neuropsychologia*, *42*, 299–319.

Girkin, C. A., & Miller, N. R. (2001). Central disorders of vision in humans. *Survey of Ophthalmology*, *45*, 379–405.

Hauk, O., Johnsrude, I., & Pulvermüller, F. (2004). Somatotopic representation of action words in human motor and premotor cortex. *Neuron*, *41*, 301–307.

Jefferies, E., & Lambon Ralph, M. A. (2006). Semantic impairment in stroke aphasia versus semantic dementia: A case-series comparison. *Brain*, *129*, 2131–2147.

Khader, P. H., Jost, K., Mertens, M., Bien, S., & Rösler, F. (2010). Neural correlates of generating visual nouns and motor verbs in a minimal phrase context. *Brain Research*, *1318*, 122–132.

Lynott, D., & Connell, L. (2009). Modality exclusivity norms for 423 object properties. *Behavior Research Methods*, *41*, 558–564.

Manning, L. (2000). Loss of visual imagery and defective recognition of parts of wholes in optic aphasia. *NeuroCase*, *6*, 111–128.

Marques, J. F. (2007). The general/specific breakdown of semantic memory and the nature of superordinate knowledge: Insights from superordinate and basic-level feature norms. *Cognitive Neuropsychology*, *24*, 879–903.

Martin, A., Haxby, J. V., Lalonde, F. M., Wiggs, C. L., & Ungerleider, L. G. (1995). Discrete cortical regions associated with knowledge of color and knowledge of action. *Science*, *270*, 102–105.

Mårtensson, F., Roll, M., Apt, P., & Horne, M. (2011). Modeling the meaning of words: Neural correlates of abstract and concrete word processing. *Acta Neurobiologiae Experimentalis*, *71*, 455–478.

Mårtensson, F., Öberg, C., & Horne, M. (2012). Correlations of Swedish and English word ratings of imageability, familiarity and age of acquisition. Manuscript in preparation.

Patterson, K., Nestor, P. J., & Rogers, T. T. (2007). Where do you know what you know? The representation of knowledge in the human brain. *Nature Reviews Neuroscience*, *8*, 976–987.

Pulvermüller, F., Preissl, H., Lutzenberger, W., & Birbaumer, N. (1996). Brain rhythms of language: Nouns versus verbs. *European Journal of Neuroscience*, *8*, 937–941.

Pulvermüller, F., & Fadiga, L. (2010). Active perception: Sensorimotor circuits as a cortical basis for language. *Nature Reviews Neuroscience*, *11*, 351–360.

Rogers, T. T., & Patterson, K. (2007). Object categorization: Reversals and explanations of the basic-level advantage. *Journal of Experimental Psychology*, *136*, 451–469.

Rosch, E. (1978). Principles of categorization. In E. Rosch & B. B. Lloyd (Eds.), *Cognition and categorization* (pp. 27–48). Hillsdale, NJ: Lawrence Erlbaum.

Sabsevitz, D. S., Medler, D. A., Seidenberg, M., & Binder, J. R. (2005). Modulation of the semantic system by word imageability. *Neuroimage*, *27*, 188–200.

Shapiro, K. A., Moo, L. R., & Caramazza, A. (2006). Cortical signatures of noun and verb production. *PNAS*, *103*, 1644–1649.

Tomasino, B., Weiss, P. H., & Fink, G. R. (2010). To move or not to move: Imperatives modulate action-related verb processing in the motor system. *Neuroscience*, *169*, 246–258.

Warrington, E. K., & Shallice, T. (1984). Category specific semantic impairments. *Brain*, *107*, 829–853.

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 "#"

<table>
<tr><td colspan="2">1. Wrong superordinate (level 5) category: Test word *fjäril* "butterfly" categorized as *växt* "plant" instead of *djur* "animal" or *insekt* "insect"</td></tr>
<tr><td>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.</td><td>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.</td></tr>
<tr><td colspan="2">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]</td></tr>
<tr><td>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.</td><td>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.</td></tr>
<tr><td colspan="2">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).</td></tr>
<tr><td><***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.**</td><td><***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**.</td></tr>
<tr><td colspan="2">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").</td></tr>
<tr><td>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.</td><td>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.</td></tr>
</table>

[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 #.

Paper II

Nor Jnl Ling 38.3, 351–364 © Nordic Association of Linguists 2015 doi:10.1017/S0332586515000220

Blomberg, Frida & Carl Öberg. 2015. Swedish and English word ratings of imageability, familiarity and age of acquisition are highly correlated. *Nordic Journal of Linguistics* 38(3), 351–364.

SHORT COMMUNICATION

Swedish and English word ratings of imageability, familiarity and age of acquisition are highly correlated

Frida Blomberg & Carl Öberg

At present, there is no comprehensive psycholinguistic database containing Swedish words with ratings of word properties such as e.g. imageability, although researchers carrying out psycholinguistic studies in Swedish face the need to be able to control for and systematically vary such properties. The present study addressed this issue by investigating the possibility of transferring English word ratings to Swedish. IMAGEABILITY, FAMILIARITY and AGE OF ACQUISITION (AoA) ratings were obtained for a sample of Swedish words (N = 99). These ratings were then compared with the corresponding English ratings from the Medical Research Council (MRC) Psycholinguistic Database (Coltheart 1981) using Spearman correlation. Swedish and English word ratings were found to be highly correlated for imageability and AoA, and moderately correlated for familiarity. Following these results, we suggest that, in general, ratings of these variables can be reliably transferred between the two languages, although some caution should be taken, since for some individual words, some ratings might differ substantially for their Swedish and English translations.

Keywords word ratings, Swedish, English, imageability, age of acquisition, familiarity, psycholinguistics, lexical database construction

Frida Blomberg, Department of Linguistics, Centre for Languages and Literature, Lund University, Box 201, SE-221 00 Lund, Sweden. frida.blomberg@ling.lu.se
Carl Öberg, Department of Clinical Sciences, Biomedical Centre, BMC F11, Sölvegatan 19, SE-221 84 Lund, Sweden. carl.oberg@med.lu.se

1. INTRODUCTION

1.1 Word properties and psycholinguistic experiments

When different word types, e.g. nouns and verbs, or concrete and abstract words, are compared in psycholinguistic experiments, it is crucial to be able to systematically vary the word properties of interest, while keeping other possibly confounding variables constant. A frequently used approach for evaluating semantic as well as other word properties is to ask people to make ratings of words' properties on a Likert-type scale. For English, several research groups have gathered word ratings for different properties, among them IMAGEABILITY, CONCRETENESS, FAMILIARITY, SUBJECTIVE FREQUENCY, MEANINGFULNESS and AGE OF ACQUISITION (AoA) (Paivio, Yuille & Madigan 1968, Gilhoolie & Logie 1980, Coltheart 1981, Morrison, Chappell & Ellis 1997, Altarriba, Bauer & Benvenuto 1999, Balota, Pilotti & Cortese 2001, Bird, Franklin & Howard 2001, Stadthagen-Gonzalez & Davis 2006, Cortese & Khanna 2008, Warriner, Kuperman & Brysbaert 2013.[1] Word ratings are also available for a number of other European languages, e.g. Norwegian (Lind et al. 2015), Portugese (Marques et al. 2007) Dutch (Ghyselinck, De Moor & Brysbaert 2000) and French (Flieller & Tournois 1994). However, no similar database with word ratings is currently available for Swedish. Since collection of word ratings is a time-consuming process and a large database of rated words should ideally be available to choose stimuli from, a convenient alternative would be to be able to translate words with ratings from already existing large databases in other languages. However, this method presupposes that word ratings are similar enough across languages for transfer of ratings to be applicable. Even if words are accurately translated, their semantic content is likely to differ more or less subtly between languages (see Simonsen et al. 2013), and it can thus be argued that English word ratings might not accurately reflect the properties of Swedish words.

The present study was carried out in order to obtain a sample of Swedish word ratings for three of the above-mentioned variables (imageability, familiarity and age of acquisition), and to see whether these ratings correlated with corresponding English word ratings. If so, it would be reasonable to assume that directly transferring English word ratings of these properties to Swedish would in general be a valid method.

1.2 Imageability

Concrete words are generally processed with greater speed and accuracy than abstract words (Paivio 2010). Concreteness is related to the amount of sensory information associated with a word and is usually assessed by having subjects rate the words' imageability or concreteness on a 1–7 scale, where 1 = least imageable/concrete and 7 = most imageable/concrete. Whereas concreteness values are based on how directly a word refers to a physical object, imageability ratings are obtained on the basis of judgments of how easily a word evokes a sensory experience or 'mental image' (Paivio et al. 1968; Gillhoolie & Logie 1980; Paivio 1986, 2010). Rated concreteness is highly correlated with rated imageability, and in many studies the two terms are used interchangeably (e.g. Sabsevitz et al. 2005, Fliessbach et al. 2006, Moroschan & Westbury 2009).

1.3 Familiarity

It is well-known that word processing is affected by how common words are, and word frequencies taken from spoken or written language corpora are often used as an indication of how often a word may have been encountered. Another way to quantify people's experience with words is to ask them to rate how familiar words are on a 1–7 scale where 1 = least familiar and 7 = most familiar (Gilhoolie & Logie 1980). Familiarity ratings can be used as a complement to word frequencies, or be used in cases where word frequencies are not available, but familiarity judgments may also measure something else than just how often the words are encountered, possibly involving semantic properties. For example, Westbury (2013) found that a set of affective predictors accounted for 100% of the variance in English familiarity ratings. In some studies, familiarity has even been found to be a better predictor of word processing performance than word frequency (Stadthagen-Gonzalez & Davis 2006).

1.4 Age of acquisition (AoA)

Early acquired words can be assumed to be processed differently from words acquired later in life, and experience of earlier learned words is likely to be greater than experience of more recently learned words. The AoA variable is quantified on a 1–7 scale, where 1 = lowest age interval (0–2 years of age) and 7 = highest interval (13 years and older) (Gilhoolie & Logie 1980). Making subjective ratings of when a particular word was acquired may seem difficult and imprecise, but AoA estimates have been found to correspond reliably to objective measures of word acquisition age (Stadthagen-Gonzalez & Davis 2006).

2. METHOD

2.1 Participants and materials

Nineteen native Swedish speakers (13 female) in the age range of 19–65 years ($M = 38$, $SD = 15$) performed word ratings of imageability, familiarity and age of acquisition for 99 Swedish words. All ratings were performed anonymously. The words were all nouns denoting concrete objects and entities as well as emotions and abstract states (Appendix 1). Written word frequencies were obtained from the Stockholm Umeå Corpus (SUC; Ejerhed et al. 1992). SUC frequencies ranged from 1 to 130 occurrences per million ($M = 2.48$, $SD = 0.914$). Word length ranged from one to four syllables ($M = 24.3$, $SD = 28.021$).

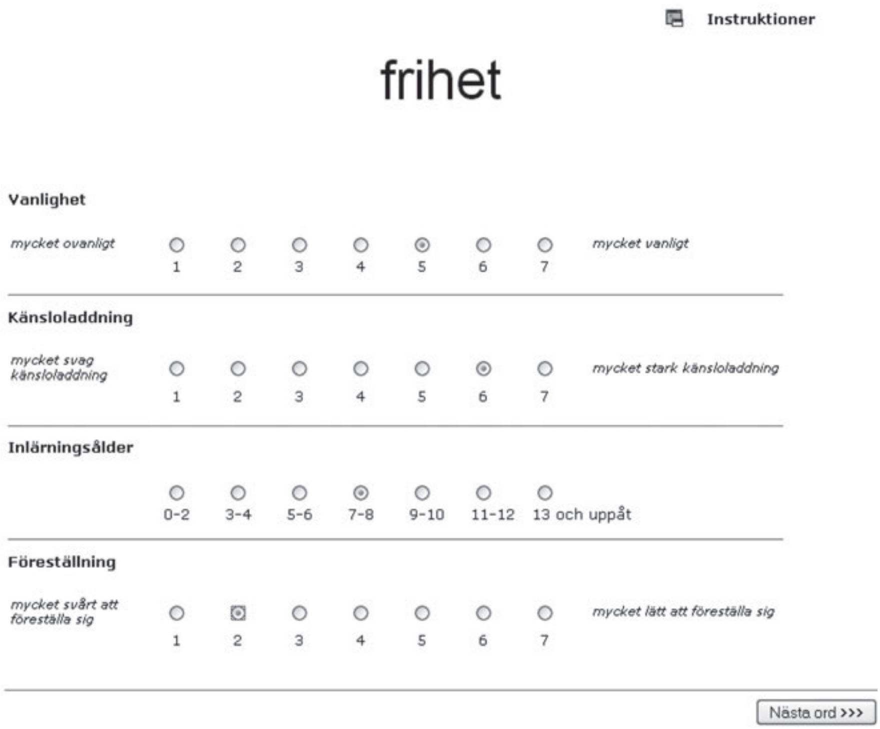


Figure 1. Screenshot of the web-based rating form.

2.2 Procedure

The word rating test was carried out as a web-based rating form (Figure 1), published on an internet page with the MIDAS software (further described in Appendix 2). All words were rated with regard to the variables *föreställning* (imageability), *vanlighet* (familiarity), *inlärningsålder* (age of acquisition) and *känsloladdning* (emotional arousal).[2] Word ratings were made on scales ranging from 1 to 7 (1 = the lowest imageability/familiarity/AoA/arousal, 7 = the highest imageability/familiarity/AoA/arousal), following translated versions of the instructions used in the Gilhoolie–Logie norms (Gilhoolie & Logie 1980), a set of rating norms which the imageability, familiarity and age of acquisition scores in the Medical Research Council (MRC) Psycholinguistic Database scores are partially based on. The words were presented in random order, with one practice word prior to the real ratings. Each word had to be rated for all variables before the next word could be accessed. It was not possible to go back and change any answers. The instructions (Appendix 3, for English instructions see Gilhoolie & Logie 1980) could be viewed at any time during the test by clicking the icon *Instruktioner* ('Instructions') at the upper right corner of the web page.

2.3 Data analysis

Scores on the 1–7-point scale were transformed by multiplying them by 100, in order to get values on the same scale as those in the MRC database (100–700). In order to see how similar the Swedish imageability, familiarity and age of acquisition ratings were to the corresponding English word ratings, all words were translated and English word ratings were obtained from the MRC database (Coltheart 1981). The MRC database was chosen since it contains a large number of English words and is easily searchable via a web-based interface.[3] The MRC database value for each English word was compared with the mean rating of each word from the present study using Spearman correlation. Written frequencies (Kucera–Francis) were obtained from the MRC database in order to see whether or not the Swedish and English word frequencies correlated. All statistical testing was performed in SPSS.

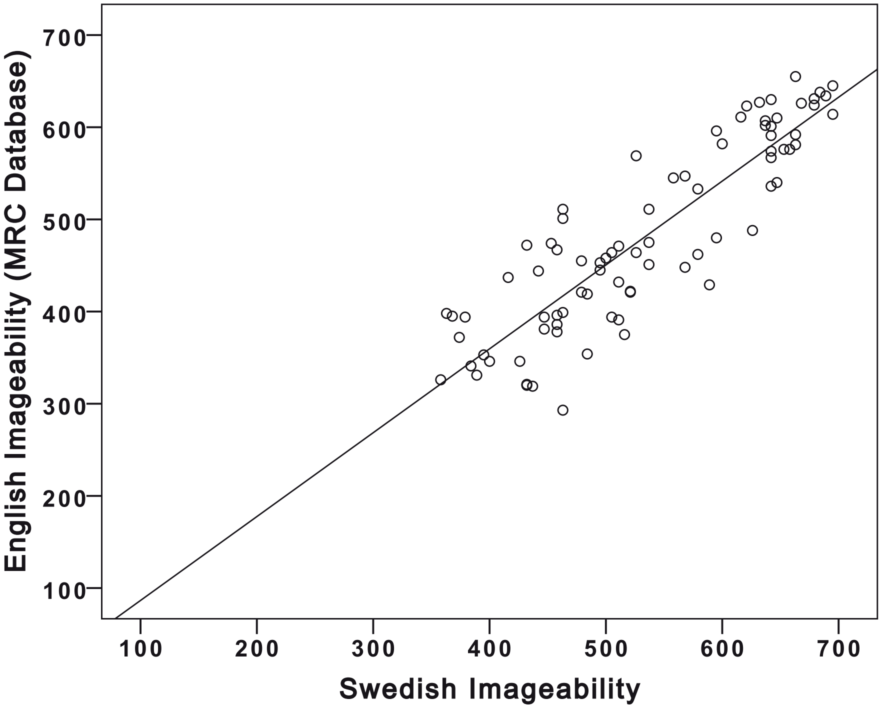
3. RESULTS

All Swedish and English words with ratings are listed in Appendix 1. As can be seen in Table 1 and Figures 2–4, all three word properties were significantly correlated between the two languages (all *p*s $< .001$). Very strong correlations were present for imageability ($r_s = .865$) and age of acquisition ($r_s = .816$) and a moderate correlation was seen for familiarity, ($r_s = .393$). The range of familiarity values was more restricted than the range of the other variables (see Table 1), i.e. the words were generally considered to be rather familiar, possibly contributing to the lower correlation for this variable. Statistical testing with Pearson correlation showed that written word frequencies from the SUC (Ejerhed et al. 1992) and the MRC database (Coltheart 1981) correlated ($r = .473$, $p < .001$)

	Swedish			English			Correlation	
	M	SD	Range	M	SD	Range	Spearman rho	*p*
Ima	534	98	316–695	483	101	293–655	.865	< .001
AoA	417	128	153–674	377	129	203–606	.816	< .001
Fam	555	67	363–700	526	51	394–621	.393	< .001

Ima = imageability, AoA = age of acquisition, Fam = familiarity

Table 1. Correlations and descriptive statistics of Swedish and English word ratings.



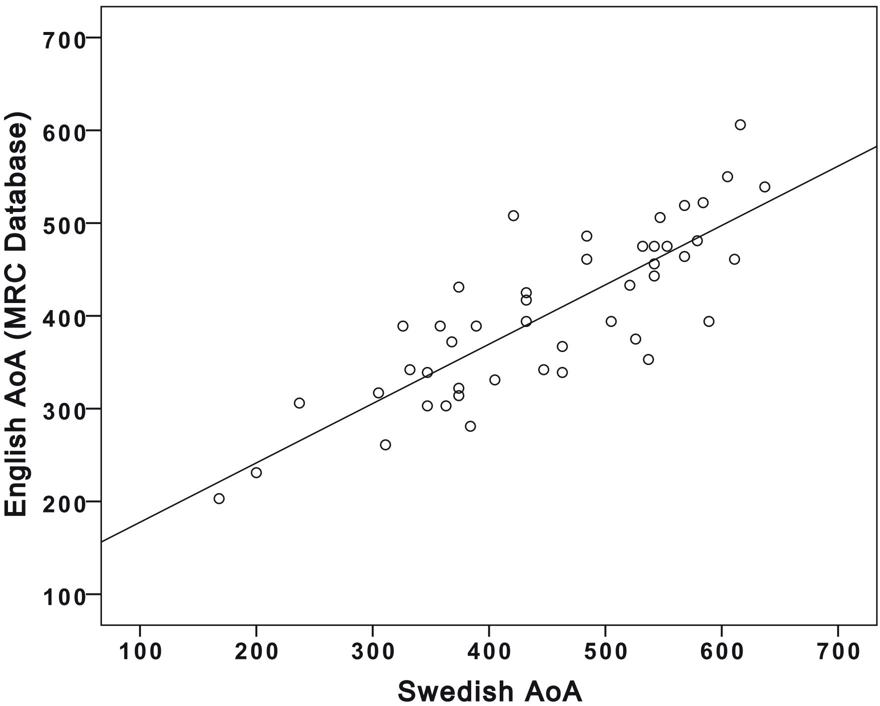
R^2 Linear = 0.776; $y = -4.42+0.91*x$

Figure 2. Scatterplot showing the correlation between English imageability ratings from the MRC database (*y* axis) and Swedish imageability ratings (*x* axis).

4. DISCUSSION

The present study compared subjects' ratings of imageability, familiarity and age of acquisition in a sample of Swedish nouns with the ratings of their English translations in the MRC database. The Swedish word ratings were moderately to strongly correlated with the English ratings, indicating that MRC database values can be reliably transferred to Swedish translations of the words. This opens up the possibility of translating a large number of already available English word ratings and using the Swedish translations of the words for psycholinguistic experiments. It should, however, be noted, that since written word frequencies also correlated between the two languages, this might account for some of the shared variance in word ratings.[4]

Although the present study showed that transferring word ratings is a valid option in the absence of Swedish ratings (and even as a complement to Swedish word ratings if they existed but did not comprise the same set of words), it should be stressed that there would be several advantages of a genuine Swedish database. One advantage would be that, other variables whose values cannot be transferred, such

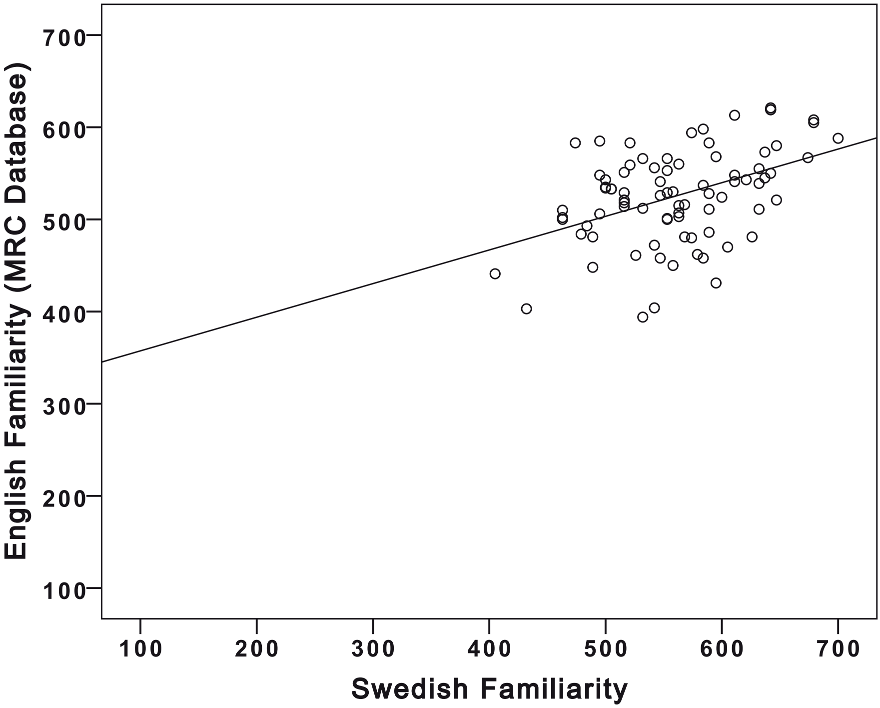


R^2 Linear = 0.684; $y = 1.14E2{+}0.64*x$

Figure 3. Scatterplot showing the correlation between English age of acquisition ratings from the MRC database (*y* axis) and Swedish age of acquisition ratings (*x* axis).

as word frequencies and data concerning form-based word properties, could also be included in such a database. It is also the case that some word meanings (especially highly culture-specific ones) might be difficult to translate and ratings of such words' properties can be expected to differ between languages (Simonsen et al. 2013). In the present study, some words exhibited larger variation between their Swedish and English ratings. Examples of this include the Swedish word *sorg* 'sorrow', which was rated lower in imageability compared to the English word *sorrow* (429 compared to 589), but higher in familiarity (589 compared to 486). Swedish *ilska* 'anger' was rated as being substantially more imageable (626) than English *anger* (488). The Swedish word *position* 'position' had a notably higher AoA rating (526) than its English translation *position* (375). One explanation for this variation might be that these words' meanings do not overlap entirely between the two languages.

Furthermore, there are word properties other than the ones compared in the present study that may be less correlated between the two languages (e.g. meaningfulness, Coltheart 1981) as well as other variables, not available in the MRC database, which it might be useful to have Swedish ratings for (e.g. abstract conceptual features (Crutch et al. 2013). Thus, in the long run it would be ideal to



R^2 Linear = 0.192; $y = 3.21E2+0.36*x$

Figure 4. Scatterplot showing the correlation between English familiarity ratings from the MRC database (*y* axis) and Swedish familiarity ratings (*x* axis).

create a Swedish database, preferably searchable via a web-based interface, similar to e.g. the MRC database (Coltheart 1981) and Norwegian Words (Lind et al. 2015).

Finally, Swedish and English are structurally similar languages, spoken in similar cultures. Thus, although the results offer support for transferring word ratings between these two languages, they might be less generalizable for translations across less similar languages and cultures. The field would benefit from extending the cross-linguistic comparisons to other languages. Swedish ratings could be compared to those already available in, for example, Norwegian, French, Dutch and Portugese and, ideally, also to word ratings in languages outside of the Indo-European language family.

ACKNOWLEDGEMENTS

This research was supported by the Swedish Research Council: grant 421-2004-8918. We would like to express our gratitude to two anonymous reviewers, whose constructive feedback has greatly improved the paper.

APPENDIX 1

Words with ratings

Ima = imageability, Fam = familiarity, AoA = age of acquisition, Emo = emotional arousal; Swe = Swedish, Eng = English

CONCRETE Swedish	English	Ima Swe	Ima Eng	Fam Swe	Fam Eng	AoA Swe	AoA Eng	Emo Swe
Fönster	Window	637	602	642	621	200	231	216
Klocka	Clock	695	614	679	608	195	—	226
Telefon	Telephone	663	655	679	605	195	—	268
Roman	Novel	568	547	558	530	553	475	337
Eld	Fire	689	634	647	580	205	—	400
Stuga	Cottage	637	607	621	543	268	—	295
Mjölk	Milk	684	638	700	588	153	—	300
Soffa	Couch	642	536	647	521	200	—	263
Cigarett	Cigarrette	695	645	637	573	289	—	395
Uniform	Uniform	642	591	479	484	405	331	479
Silver	Silver	600	582	589	528	305	317	295
Kamera	Camera	653	576	642	550	263	—	258
Dragspel	Accordion	658	576	532	394	353	—	295
Varg	Wolf	647	610	584	537	405	—	342
Madrass	Mattress	642	601	600	524	274	—	242
Paraply	Umbrella	663	592	632	511	237	306	237
Diamant	Diamond	621	623	532	512	347	339	332
Fjäril	Butterfly	679	624	626	481	205	—	405
Näckros	Waterlily	668	—	458	—	379	—	295
Persilja	Parsley	663	—	579	—	389	—	279
Kameleont	Chameleon	511	—	363	—	511	—	242
Papegoja	Parrot	658	—	558	—	258	—	247
Tegelsten	Brick	642	574	553	529	311	261	168
Jordgubbe	Strawberry	679	631	632	539	189	—	421
Termometer	Thermometer	663	581	568	481	326	389	237
Vulkan	Volcano	632	627	526	461	363	—	432
Purjolök	Leek	647	540	595	431	389	389	242
Gräshoppa	Grasshopper	642	630	563	507	274	—	205
Humla	Bumblebee	647	—	616	—	226	—	295
Apelsin	Orange	668	626	674	567	168	203	237
Hasselnöt	Hazelnut	611	—	547	—	358	—	221
Blomkål	Cauliflower	642	567	579	462	347	—	211
Påsklilja	Daffodil	616	611	542	404	379	—	311

ABSTRACT Swedish	English	Ima Swe	Ima Eng	Fam Swe	Fam Eng	AoA Swe	AoA Eng	Emo Swe
Tradition	Tradition	484	354	547	526	484	486	411
Frihet	Freedom	416	437	595	568	432	425	616
Position	Position	426	346	521	559	526	375	253
Kombination	Combination	358	326	484	493	542	475	132
Reaktion	Reaction	368	395	505	533	547	506	289
Variation	Variety	374	372	505	533	568	464	237
Fest	Party	595	596	642	619	347	—	453
Hemlighet	Secret	453	—	600	—	284	—	505
Attityd	Attitude	432	321	553	553	579	481	405
Rykte	Rumour	395	353	563	503	484	461	447
Ideal	Ideal	389	331	516	521	611	461	463
Löfte	Promise	432	320	584	598	395	—	553
Moral	Morale	384	341	500	535	637	539	547
Ritual	Ritual	453	474	432	403	589	—	337
Favorit	Favourite	458	378	574	594	363	303	453
Plikt	Duty	400	346	500	543	563	—	400
Datum	Date	463	501	611	613	374	314	200
Kaos	Chaos	526	464	558	450	526	—	542
Överflöd	Abundance	458	386	489	448	568	519	395
Mysterium	Mystery	432	548	495	472	447	342	432
Ironi	Irony	463	293	547	458	616	606	495
Önskning	Wish	463	399	542	556	326	—	474
Spekulation	Speculation	316	—	437	—	637	—	300
Prestige	Prestige	379	394	405	441	674	—	442
Uppehåll	Break	363	398	516	529	500	—	268
Mognad	Maturity	400	—	521	—	526	—	363
Charm	Charm	479	455	516	514	542	456	474
Magi	Magic	500	458	489	481	384	281	432
Visdom	Wisdom	447	381	463	510	532	475	342
Gästfrihet	Hospitality	416	—	421	—	584	—	395
Välgörenhet	Charity	495	445	516	518	521	433	442
Påhitt	Idea	437	319	495	585	379	—	400
Lydnad	Obedience	447	394	463	500	374	—	463

EMOTION Swedish	English	Ima Swe	Ima Eng	Fam Swe	Fam Eng	AoA Swe	AoA Eng	Emo Swe
Kärlek	Love	526	569	642	619	347	303	653
Glädje	Joy	579	533	637	545	332	342	663
Oro	Anxiety	521	422	611	548	442	—	611
Sorg	Sorrow	589	429	589	486	432	394	663
Lycka	Happiness	547	—	621	—	374	—	632
Spänning	Excitement	500	—	574	—	400	—	532

Lust	Lust	442	444	542	472	474	—	542
Längtan	Yearning	532	—	521	—	379	—	605
Humor	Humour	579	462	542	555	432	417	542
Skräck	Horror	558	545	553	501	368	372	632
Tröst	Comfort	479	421	532	566	479	—	447
Skam	Shame	484	419	500	534	463	367	626
Förvåning	Surprise	537	451	589	583	374	322	463
Ilska	Anger	626	488	611	541	353	—	658
Besvikelse	Disappointment	505	—	600	—	432	—	605
Nyfikenhet	Curiousity	505	394	563	515	358	389	479
Stress	Stress	558	—	637	—	505	—	621
Lättnad	Relief	511	432	516	551	542	443	547
Chock	Shock	695	471	637	560	289	—	395
Irritation	Irritation	568	448	605	470	421	508	584
Entusiasm	Enthusiasm	505	464	495	506	584	522	484
Passion	Passion	458	467	463	502	611	—	553
Förälskelse	Crush	595	480	574	480	463	339	611
Depression	Depression	495	453	547	541	605	550	563
Njutning	Pleasure	537	511	521	583	505	394	574
Medlidande	Pity	511	391	568	516	537	353	579
Avundsjuka	Envy	516	375	589	511	374	431	595
Svartsjuka	Jealousy	537	475	553	500	479	—	605
Trivsel	Comfort	479	421	532	566	479	—	447
Tacksamhet	Gratitude	458	396	584	458	474	—	553
Välbehag	Pleasure	537	511	521	583	505	394	574
Avsmak	Disgust	495	—	395	—	605	—	489
Rastlöshet	Restlessness	505	—	484	—	553	—	442

APPENDIX 2

Method for data collection and database construction

The present study was carried out using the software MIDAS (Mysql Interface and Database Abstraction System). MIDAS is a web content and database management system which can be used to gather various sources of linguistic data and make them easily accessable and searchable through a common interface where search criteria for various parameters, e.g. word frequency, word class and other variables can be specified. MIDAS was used for creating the word rating web page as well as for organizing the data. With MIDAS, all data entered into the system can be downloaded as a .csv-file and directly imported to SPSS for statistical testing.

Word frequencies were obtained from the Stockholm Umeå Corpus (SUC) (Ejerhed et al. 1992) and the Gothenburg Spoken Language Corpora (GSLC) (Alwood 1999), the number of syllables for each word was manually counted, and this information was entered into the database together with data from the MRC database and the word ratings obtained in the present study. In this way, a mini-database was constructed. For access to the database, please contact the first author of the present study: frida.blomberg@ling.lu.se.

APPENDIX 3

Swedish instructions

Instruktioner

Du kommer att få poängsätta ett antal ord gällande några olika egenskaper. En skala med 7 steg kommer att användas i samtliga fall. Känn dig fri att använda hela skalan, men bry dig inte om hur ofta du använder en viss siffra så länge den motsvarar din verkliga bedömning av ordet. Det är inte meningen att du ska lägga ner lång tid på varje fråga – fyll i testet ganska snabbt och baserat på din intuition, men reflektera ändå över frågorna innan du svarar. Observera också att det inte finns några "rätt" eller "fel" svar, utan syftet med testet är att du ska ge en bild av hur du uppfattar orden.

Här kommer ordegenskaperna som du kommer att bedöma:

1) Vanlighet Det varierar hur vanliga olika ord är, dvs hur ofta de förekommer i vardagen och hur välbekanta de känns. En del ord är mycket välbekanta, medan andra kan vara mindre välbekanta eller nästan helt okända. Din uppgift är att poängsätta ordens vanlighet, beroende på hur vanliga du upplever att de är. Skalan sträcker sig från 1–7, där **1 är mycket ovanligt** och **7 är mycket vanligt**. De ord som du upplever som mycket vanliga ska alltså ges en hög vanlighetspoäng. De ord som du upplever som mycket ovanliga ska ges en låg vanlighetspoäng.

2) Känsloladdning Det varierar hur starkt olika ord är associerade med känsloupplevelser. En del ord väcker inre känslor som kan vara starkt positiva eller negativa, andra ord kan väcka mindre tydliga känsloupplevelser, och ytterligare ord är helt neutrala och väcker ingen känsloupplevelse alls. Din uppgift är att poängsätta ordens känsloladdning, beroende på hur starka känslor de väcker. Skalan sträcker sig mellan 1–7, där **1 motsvarar ett helt neutralt ord** och **7 ett starkt känsloladdat ord**. De ord som väcker starka känsloassociationer ska ges en hög känsloladdningspoäng. De ord som i mycket liten utsträckning eller inte alls väcker känsloassociationer ska ges en låg känsloladdningspoäng.

3) Inlärningsålder I vilken ålder kan du uppskattningsvis ha lärt dig ordet? En skala med 7 åldersintervall kommer att användas. Intervallen är **0–2 år**, **3–4 år**, **5–6 år**, **7–8 år**, **9–10 år**, **11–12 år** samt **13 år och uppåt**.

4) Föreställningar Det varierar hur lätt olika ord väcker inre föreställningar av t.ex. saker, händelser eller upplevelser. En del ord väcker snabbt och lätt **föreställningar av synintryck, ljudintryck, känselintryck, lukter och smaker**, medan andra ord kan göra det med viss ansträngning (t.ex. efter en lång fördröjning) och vissa ord väcker inte någon inre föreställning alls. Din uppgift är att poängsätta orden beroende på hur lätt de väcker inre föreställningar. Skalan sträcker sig mellan 1–7, där **1 är svårast att föreställa sig** och **7 är lättast att föreställa sig**. De ord som snabbt och lätt väcker inre föreställningar ska ges en hög föreställbarhetspoäng. De ord som med svårighet eller inte alls väcker inre föreställningar ska ges en låg föreställbarhetspoäng.

NOTES

1. There are also studies that aim to computationally extrapolate estimates for the whole dictionary from human word ratings (Westbury et al. 2013).

2. This variable was not compared to English, since the MRC database does not contain values for emotional arousal, but the values are nevertheless reported in Appendix 1. A 1–7 point scale similar to that for the other variables was created for emotional arousal for the present study with 1 = least emotionally arousing and 7 = most emotionally arousing.
3. The MRC database can be accessed via a web-based interface (http://websites.psychology.uwa.edu.au/school/MRCDatabase/uwa_mrc.htm), where the preferred range of values of different variables can be specified and word lists are given as output. It is also possible to download the entire MRC database free of charge.
4. We would like to thank an anonymous reviewer for pointing this out.

REFERENCES

Allwood, Jens. 1999. The Swedish Spoken Language Corpus at Göteborg University. *Fonetik 99* (Gothenburg Papers in Theoretical Linguistics 81). Göteborg: University of Göteborg, Department of Linguistics.

Altarriba, Jeanette, Lisa M. Bauer & Claudia Benvenuto. 1999. Concreteness, context availability, and imageability ratings and word associations for abstract, concrete, and emotion words. *Behavioral Research Methods* 31, 578–602.

Balota, David A., Maura Pilotti & Michael J. Cortese. 2001. Subjective frequency estimates for 2,938 monosyllabic words. *Memory & Cognition* 29, 639–647.

Bird, Helen, Sue Franklin & David Howard. 2001. Age of acquisition and imageability ratings for a large set of words, including verbs and function words. *Behavior Research Methods, Instruments, & Computers* 33, 73–79.

Coltheart, Max. 1981. The MRC Psycholinguistic Database. *Quarterly Journal of Experimental Psychology* 33A, 497–505.

Cortese, Michael J. & Maya M. Khanna. 2008. Age of acquisition ratings for 3,000 monosyllabic words. *Behavior Research Methods* 40, 791–794.

Crutch, Sebastian, Joshua Troche, Jamie Reilly & Gerard R. Ridgway. 2013. Abstract conceptual feature ratings: The role of emotion, magnitude, and other cognitive domains in the organization of abstract conceptual knowledge. *Frontiers in Human Neuroscience* 7:186.

Ejerhed, Eva, Gunnel Källgren, Ola Wennstedt & Magnus Åström. 1992. *The Linguistic Annotation System of the Stockholm–Umeå Corpus Project* (Technical Report 33). Umeå: Department of General Linguistics, Umeå University.

Flieller, André & Jocelyne Tournois. 1994. Imagery value, subjective and objective frequency, date of entry into the language, and degree of polysemy in a sample of 998 French words. *International Journal of Psychology* 29, 471–509.

Fliessbach, Klaus., Susanne Weis, Peter Klaver, Christian E. Elger & Bernd Weber. 2006. The effect of word concreteness on recognition memory. *NeuroImage* 32, 1413–1421.

Ghyselinck, Mandy, Wendy De Moor & Marc Brysbaert. 2000. Age-of-acquisition ratings for 2,816 Dutch four- and five-letter nouns. *Psychologica Belgica* 40, 77–98.

Gilhoolie, Ken J. & Robert H. Logie. 1980. Meaning-dependent ratings of imagery, age of acquisition, familiarity, and concreteness for 387 ambiguous words. *Behaviour Research Methods & Instrumentation* 12(4), 428–450.

Lind, Marianne, Hanne Gram Simonsen, Pernille Hansen, Elisabeth Holm & Bjørn-Helge Mevik. 2015. Norwegian words: A lexical database for clinicians and researchers. *Clinical Linguistics & Phonetics* 29(4), 276–290.

Marques, J. Frederico, Fransisca L. Fonseca, A. Sofia Morais & Inês A. Pinto. 2007. Estimated age of acquisition norms for 834 Portuguese nouns and their relation with other psycholinguistic variables. *Behavior Research Methods* 39, 439–444.

Moroschan, Gail & Chris Westbury. 2009. Imageability x phonology interactions during lexical access: Effects of modality, phonological neighborhood, and phonological processing efficiency. *The Mental Lexicon* 4(1), 115–145.

Morrison, Catriona M., Tameron D. Chappell & Andrew W. Ellis. 1997. Age of acquisition norms for a large set of object names and their relation to adult estimates and other variables. *The Quarterly Journal of Experimental Psychology* 50A, 528–559.

Paivio, Allan. 1986. *Mental Representations: A Dual Coding Approach*. New York: Oxford University Press.

Paivio, Allan. 2010. Dual coding theory and the mental lexicon. In Merle Horne & Mikael Roll (eds.), *Words and their Meaning: A Deep Delve from Surface Distribution into Underlying Neural Representation*: Special issue of *The Mental Lexicon* 5(2), 205–230.

Paivio, Allan, John C. Yuille & Stephen A. Madigan. 1968. Concreteness, imagery, and meaningfulness values for 925 nouns. *Journal of Experimental Psychology: Monograph Supplement* 76(1, Part 2), 1–25.

Sabsevitz, David S., David A. Medler, Mark Seidenberg & Jeffrey R. Binder. 2005. Modulation of the semantic system by word imageability. *NeuroImage* 27, 188–200.

Simonsen, Hanne Gram, Marianne Lind, Pernille Hansen, Elisabeth Holm & Bjørn-Helge Mevik. 2013. Imageability of Norwegian nouns, verbs and adjectives in a cross-linguistic perspective. *Clinical Linguistics and Phonetics* 27(6–7), 435–446.

Stadthagen-Gonzalez, Hans & Colin J. Davis. 2006. The Bristol norms for age of aquisition, imageability, and familiarity. *Behavioral Research Methods* 38(4), 598–605.

Warriner, Amy Beth, Victor Kuperman & Marc Brysbaert. 2013. Norms of valence, arousal, and dominance for 13,915 English lemmas. *Behavior Research Methods* 45(4), 1191–1207.

Westbury, Chris. 2013. You can't drink a word: Lexical and individual emotionality affect subjective familiarity judgments. *Journal of Psycholinguistic Research* 43(5), 631–649.

Westbury, Chris F., Cyrus Shaoul, Geoff Hollis, Lisa Smithson, Benny B. Briesemeister, Markus J. Hofmann & Arthur M. Jacobs. 2013. Now you see it, now you don't: On emotion, context, & the algorithmic prediction of human imageability judgments. *Frontiers in Psychology* 4:991.

Paper III

Emotional arousal and lexical specificity modulate response times differently depending on ear of presentation in a dichotic listening task

Frida Blomberg,* Mikael Roll,* Magnus Lindgren,**
K. Jonas Brännström,*** and Merle Horne*
* Dept. of Linguistics and Phonetics, Lund University / ** Dept. of Psychology, Lund University / *** Dept. of Logopedics, Phoniatrics and Audiology, Lund University

We investigated possible hemispheric differences in the processing of four different lexical semantic categories: SPECIFIC (e.g. *bird*), GENERAL (e.g. *animal*), ABSTRACT (e.g. *advice*), and EMOTIONAL (e.g. *love*). These wordtypes were compared using a dichotic listening paradigm and a semantic category classification task. Response times (RTs) were measured when participants classified testwords as *concrete* or *abstract*. In line with previous findings, words were expected to be processed faster following right-ear presentation. However, lexical specificity and emotional arousal were predicted to modulate response times differently depending on the ear of presentation. For left-ear presentation, relatively faster RTs were predicted for SPECIFIC and EMOTIONAL words as opposed to GENERAL and ABSTRACT words. An interaction of ear and wordtype was found. For right-ear presentation, RTs increased as testwords' imageability decreased along the span SPECIFIC–GENERAL–EMOTIONAL–ABSTRACT. In contrast, for left ear presentation, EMOTIONAL words were processed fastest, while SPECIFIC words gave rise to long RTs on par with those for ABSTRACT words. Thus, the prediction for EMOTIONAL words presented in the left ear was borne out, whereas the prediction for SPECIFIC words was not. This might be related to previously found differences in processing of stimuli at a global or local level.

Keywords: abstract words, concrete words, emotional words, lexical specificity, imageability, dichotic listening, neural correlates of language, semantic representation, right hemisphere, left hemisphere

The Mental Lexicon 10:2 (2015), **221–246.** DOI 10.1075/ml.10.2.03blo
ISSN 1871–1340 / E-ISSN 1871–1375

Lexical Semantics and the Brain

Word processing gives rise to different kinds of neural activation depending on the nature of the semantic information associated with words (Binder, Westbury, McKiernan, Possing, & Medler, 2005; Hauk & Pulvermüller, 2004; Khader, Jost, Mertens, Bien, & Rösler, 2010; Sandberg & Kiran, 2014). In some cases, the left and right hemispheres contribute differently to meaning processing. Thus, whereas abstract word meaning processing engages left-hemispheric structures to a larger extent (Binder et al., 2005), the processing of emotional information can be more right-hemisphere lateralized (Borod, Andelman, Obler, Tweedy, & Wilkowitz, 1992; Buchanan, Lutz, Mirzazade, Specht, Shah, Zilles, & Jäncke, 2000). It is still less known, however, how different degrees of word specificity (e.g. the GENERAL word *vegetable* vs. the SPECIFIC word *carrot*) affect hemispheric lateralization. Like emotional words, the meaning of words at a general semantic level share characteristics with both concrete and abstract word meanings. In the present study, words differing in emotional arousal and semantic specificity were compared using a dichotic listening task, with the aim of gaining insights into possible hemispheric differences in the processing of these wordtypes.

Hemispheric Lateralization of Lexical Semantic Processing

In the majority of the population, the left hemisphere (LH) is language-dominant. As an indication of this, aphasia is most commonly the result of LH lesions, and temporary anaesthetization of the left, but not the right hemisphere (RH), disrupts speech production (Wada & Rasmussen, 1960). Today, neuroimaging studies of both healthy and clinical populations using silent word generation and naming tasks (Pujol, Deus, Losilla, & Capdevila, 1999; Rutten, Ramsey, van Rijen, Alpherts, & van Veelen, 2002) can also be added to the literature supporting a LH dominance for language processing. As regards speech perception and speech recognition, a division between a bilateral ventral speech processing stream and a strongly LH-dominant dorsal stream has been suggested (Hickok & Poeppel, 2007).

However, in contrast to this left-hemispheric dominance for language, certain linguistic parameters have been found to be more RH dependent, for example the processing of emotion-related information such as emotional prosody (Buchanan et al., 2000; Ley & Bryden, 1982) and emotional words and sentences (Borod et al., 1992). As regards words' degree of concreteness, the processing of written abstract words has been found in fMRI studies to give rise to more left-lateralized activation of areas involved in phonological and verbal working memory processes, for example the left frontal cortex, whereas the processing of concrete word meaning has been associated with wide-spread, bilateral activity including sensory cortices (Binder et al., 2005; Sabsevitz, Medler, Seidenberg, & Binder, 2005; Sandberg & Kiran, 2014). Further supporting this finding, similar differences have been seen in memory performance for concrete and abstract words presented to the two hemispheres via the left visual field (LVF) and right visual field (RVF), respectively (Oliveira, Perea, Ladera, & Gamito, 2013). Recall of concrete words was more accurate when they were presented to the LVF/RH, whereas abstract words were better recalled when presented to the RVF/LH, supporting the idea that the RH may be more involved in mental imagery processes associated with concrete words.

In studies where test words were presented orally (Mårtensson, Roll, Apt, & Horne, 2011; Roll, Mårtensson, Sikström, Apt, Arnling-Bååth, & Horne, 2012), participants with aphasia due to LH lesions were seen to have greater difficulties producing associations to words at higher levels of abstraction, with the exception of one participant with anomia due to lesions to the left occipital lobe (further described in Mårtensson, Roll, Lindgren, Apt, & Horne, 2014). This speaker showed the opposite pattern, i.e. difficulties making word associations to concrete words, possibly due to lack of access to visual semantic features. A number of cases with spared abstract linguistic or conceptual knowledge following either semantic dementia or stroke affecting posterior cortical areas have been reported (cf. Warrington 1975; Crutch & Warrington, 2003). For an overview of additional cases, see Westbury, Shaoul, Hollis, Smithson, Briesemeister, Hofmann, & Jacobs (2013).

The results from the above mentioned studies are in line with the 'dual coding theory' (Paivio, 1990; 2010) which proposed that abstract words are stored in the mental lexicon mainly in the form of a "verbal" code (i.e. associated lexical items and discourse), whereas concrete words in addition are represented in terms of a "non-verbal" or "imagery" code (i.e. associated sensory information, of which visual information often constitutes a prominent component). Thus, although there is evidence that language is mainly LH lateralized, the processing of some aspects of word meaning may rather be more RH lateralized.

The assumption that the RH is involved in mental imagery and concrete word processing could be related to the degree of meaning specificity (described by e.g. Rosch (1976) in terms of subordinate/basic/superordinate levels of semantic categorization). Assuming that the RH is superior in mental imagery, it might be more involved in processing words whose referents are associated with detailed visual information (e.g. *carrot*) than words with more general, less visually specific meanings (e.g. *vegetable*). Results supporting this line of thought were obtained by Laeng, Zarrinpar, and Kosslyn (2003), who showed that the RH was superior in identifying pictures for concrete concepts at semantically specific levels (e.g. classifying a picture of a squirrel as a *squirrel*) as opposed to the LH, which instead showed an advantage in identifying pictures of concepts at a superordinate, more general level (e.g. classifying a picture of a squirrel as a *rodent*). However, since their task involved processing pictures, it is still an empirical question whether similar differences would be found when test stimuli are presented as spoken words differing in semantic specificity. The present study thus aimed to target possible differences in processing meaning at the lexical semantic level using a dichotic listening paradigm.

Testing Hemispheric Differences in Semantic Processing with Dichotic Listening

Dichotic listening studies have been widely used to investigate hemispheric specialization in the processing of sounds. Typically, different auditory stimuli are presented simultaneously to the right and left ear, e.g. CV syllables with different consonants (Hugdahl, 2000). In healthy, right-handed participants, results point to a right-ear advantage/left-hemisphere dominance for processing speech sounds. A possible explanation for this right-ear advantage (REA) is that the right ear has a more direct neural pathway to the left, language-dominant hemisphere involving more nerve fibres and thus more cortical activity than the ipsilateral pathway (Kimura, 1967; Yasin, 2007).

In addition to its application to studies on processing of speech sounds, the dichotic listening method can also be used to investigate the processing of word meaning. Studies using dichotic listening to compare the relative hemispheric lateralization of the processing of different categories of word meaning are few. However, there are some early dichotic listening studies involving semantic processing. Prior, Cumming, and Hendy (1984) compared abstract and concrete words in a dichotic listening experiment using a word recognition task, but did not find any significant differences in accuracy depending on ear of presentation. Ely, Graves, and Potter (1989) compared abstract, concrete and emotional words using a dichotically presented semantic task (categorizing words as abstract, concrete or emotional). They found a stronger REA for categorizing abstract words, whereas this effect was relatively smaller for emotional as well as concrete words. As discussed by the authors, a reason that they obtained significant results, while Prior et al. (1984) did not, might be that the semantic judgment task requires deep semantic processing, unlike the word recognition task used by Prior et al. (1984). Ely et al. (1989) used a stimulus set mainly consisting of single syllable nouns (e.g. *truth*, *horse*, although the words belonging to the emotional category were mostly verbs and adjectives (e.g. *weep*, *dead*). Prior et al. (1984) reported that they used single syllable nouns, although no examples of the stimuli were provided in the article.

Given the above background, the aim of the present study was, firstly, to investigate whether the RH advantages for emotional and visuospatial processing found in previous studies would also be reflected in the response times for spoken words associated with emotional and visual meaning components. Secondly, in order to extend the prediction that processing of word meanings with detailed sensory information (visual features in particular) may be more RH lateralized, concrete words at two different levels of semantic specificity (further described in the sections entitled "The Present Study" and "Stimuli" below) were included in the investigation, in addition to abstract and emotional words.

The Present Study

The present study was carried out using a method based on Ely et al. (1989) but with some modifications. In a manner similar to that of Ely et al. (1989), words whose meaning differed in terms of rated imageability, which is strongly correlated with concreteness (Westbury & Moroschan, 2009),[1] and emotional content were presented dichotically together with pseudowords. Response times were measured while participants classified words as either *abstract* or *concrete*. In contrast to previous studies, the present investigation introduced an additional variable: semantic specificity. Thus, four wordtypes, all of which were nouns in order to control for possible effects of word class, were compared: SPECIFIC (e.g. *soup*), GENERAL (e.g. *food*), ABSTRACT (e.g. *advice*) and EMOTIONAL (e.g. *joy*).

Predictions: Response Times (RTs)

Firstly, overall shorter RTs for right-ear presentation were expected for all four testword categories, in line with the right-ear/LH advantage for language found in previous dichotic listening research (e.g. Hugdahl, 2000; Kimura, 1967). However, the RTs for the different testword categories were expected to differ depending on the ear of presentation. EMOTIONAL words were predicted to be processed faster than ABSTRACT (low emotional arousal) words when presented to the left-ear, in line with Borod et al. (1992) and Ely et al. (1989). Moreover, the RTs for left ear presentation for highly specific/concrete words (e.g. *soup*) were expected to be faster than RTs for words at a more general level in the same semantic hierarchy (e.g. *food*), which do not have as clearly imageable referents (cf. Laeng et al., 2003).

1. See, however, also Westbury et al. (2013) for a discussion about possible confounds of context and emotion in imageability effects.

Table 1. Predictions for *Abstract/Concrete* classifications of testword types. Imageability values are discussed in the "Stimuli" section.

Testword type	Example	Imageability	Hypothesized classification
SPECIFIC	carrot	Highest (M = 604)	*Concrete*
GENERAL	food	High, but lower than for specific words (M = 538)	mainly *Concrete*
ABSTRACT	idea	Low (M = 356)	*Abstract*
EMOTIONAL	anger	Intermediate (M = 460)	mainly *Abstract*

Predictions: Semantic Classification

Based on previous findings and the distribution of concreteness/imageability values for the four wordtypes (see "Stimuli" above), SPECIFIC and GENERAL testwords were expected to be classified mainly as *concrete*, whereas ABSTRACT and EMOTIONAL testwords were predicted to most often be categorized as *abstract*. In addition, considering the slightly lower imageability values of GENERAL words, which can be assumed to be related to relatively fewer associated sensory features than SPECIFIC words, GENERAL words were expected to be judged as *abstract* to a relatively greater degree than SPECIFIC words. EMOTIONAL words were expected to be categorized as concrete more often than ABSTRACT words, mainly due to their relatively higher imageability values, but possibly also due to their association with affective experiential information (cf. Kousta, Vigliocco, Vinson, Andrews, & Del Campo, 2011). These predictions are summarized in Table 1.

Methods

Participants

Thirty-eight native speakers of Swedish were initially recruited through advertising in the Lund University area. All participants had their hearing tested with Békésy audiometry and their handedness assessed using a revised version of the Edinburgh Handedness Scale (Oldfield, 1971), see Appendix E. In order to be included in the study, participants had to be right-handed with normal hearing defined as pure-tone hearing thresholds $\leq$ 20 dB Hearing Level (HL) (ISO 2004) for frequencies 250, 500, 1000, 2000, 4000, and 8000 Hz. Eight participants did not meet these criteria and were therefore excluded. The final sample thus consisted of 30 participants (21 female) in the age range of 20–64 years (M = 28, SD = 9.6). None of the participants reported any current or previous language difficulties.

The study was performed in conformity with the Declaration of Helsinki and informed consent was obtained from all participants prior to the test. Participants received either payment or a gift for their participation.

Stimuli

The stimuli consisted of 120 one to two syllable nouns divided into the four semantic categories described in the paragraph "The Present Study" (SPECIFIC, GENERAL, EMOTIONAL, ABSTRACT). The stimulus sets of the different categories were counterbalanced for number of syllables as well as word frequency in the Stockholm Umeå Corpus (Ejerhed, Källgren, Wennstedt, & Åström, 1992). SPECIFIC and GENERAL testwords were taken from different lexical semantic hierarchies, e.g. *bord-möbel* 'table-furniture'; *banan-frukt* 'banana-fruit'. Imageability (≈ degree of concreteness) values for English translations of the words were obtained from the MRC Psycholinguistic database (Coltheart, 1981). Mean imageability was lowest for ABSTRACT words (M = 356, SD = 57), followed by EMOTIONAL words (M = 460, SD = 67), GENERAL words (M = 538, SD = 76) and was highest for SPECIFIC words (M = 604, SD = 32). An independent-measures ANOVA with word category (SPECIFIC/GENERAL/ABSTRACT/EMOTIONAL) as fixed factor showed that imageability values differed significantly between each category (all p values < .001, Sidak correction for multiple comparisons). Ratings of emotional arousal were performed following the main experiment in the present study, and were highest for EMOTIONAL words (M = 553, SD = 83), relatively low for ABSTRACT words (M = 331, SD = 114) and lowest for SPECIFIC (M = 233, SD = 97) and GENERAL (M = 231, SD = 82) words. An independent measures ANOVA with word category (SPECIFIC/GENERAL/ABSTRACT/EMOTIONAL) as fixed factor revealed significant differences in emotional arousal between the categories. Multiple comparisons with Sidak correction showed that there were differences between all word categories (p values < .001) except for SPECIFIC and GENERAL words which had an equally low rating for emotional arousal (p = 1.0). An approximately equal number of positive and negative words were included. Following Kousta, Vinson, and Vigliocco (2009), who found that emotional arousal, regardless of emotional valence, facilitated word processing, there was no further attempt to control for or systematically vary valence.

For each test word, a corresponding pseudoword was created with the same number of syllables and the same initial consonant, or in some cases consonant cluster (e.g. *fågel-figar* /fo:gel/-/fi:gar/, *glädje-glamra* /glɛ:dje/-/glamra/). In line with the aim of the study to detect possible hemispheric differences in the processing of word meaning, pseudowords were presented along with existing words in order to restrict the presentation of testwords to one ear/hemisphere at a time.

Pseudowords were chosen since they have previously been successfully used in dichotic listening (Ely et al., 1989), and since other types of competitive stimulation (i.e. non-speech) such as white noise and crowd noise has been found to be less efficient (McFarland, McFarland, Bain, & Ashton, 1978). The full set of testwords and pseudowords used in the study is presented in Appendices A–C.

The stimuli were recorded with a Neuman U87AI microphone in an anechoic chamber using version 1.3.2-beta of Audacity® recording and editing software.[2] Word and pseudoword pairs were spoken by a female native speaker of Swedish with neutral intonation and normal speech rate. In the recording of every other pair, the pseudoword was pronounced first. The subsequent sound editing was also carried out using Audacity®. Each stimulus was cut at the onset and end of the soundwave and saved as a separate file. Files with the word and the pseudoword in the right and left channels were then created. When necessary, initial fricatives were shortened so that the stimuli aligned at the onset of the vowel. All stimuli were then normalized using MatLab to a target RMS amplitude of 17.41 dB.

Procedure

Partcipants were seated in front of a computer with a Dell EI72FP 17′ screen in a quiet room. Written instructions were displayed on the computer screen prior to the experiment. Participants were instructed to identify the real word in the word/pseudoword mixture and to classify it as either *abstract* or *concrete*. Participants were informed that concrete words were defined as those referring to something one can see and touch, abstract words as something one cannot see and touch (see Appendix D for an English translation of the full set of instructions).

The speech stimuli (word/pseudoword pairs) were presented dichotically using E-prime ver. 2.0 on a personal computer. The computer had a SIS7012 Audio Driver integrated on the motherboard and was connected to a GSI 16 Audiometer (Grason & Stadler Inc.) and a pair of circumaural California Headphones Silverado earphones. The complete equipment set-up was calibrated in accordance with IEC 60318-2 and ISO 389-8 using a Brüel and Kjaer Impulse Precision Sound Level Meter type 2209 with a 4144 microphone in a 4152 ear simulator (IEC 1998; ISO 2004). A 1000 Hz calibration tone with equal average RMS as the speech signals (17.41 dB) was used for the calibration of the speech signals.

The stimuli were presented at 70 dB SPL in a pseudorandomized order with the real word presented to the right or left ear in no more than three consecutive

2. Audacity® software is copyright (c) 1999–2015 Audacity Team. Web site: http://audacity.sourceforge.net/.

trials. There was a 3000 ms interstimulus interval during which the participant could respond before the experiment automatically moved on to the next trial. The task was to distinguish the real word and categorize it as either *concrete* or *abstract* by button press. Responses were made on a PST Serial Response Box by pressing the two rightmost keys with the right hand's index and middle finger. In order to avoid shorter response times for responses made with the index finger, the index/middle finger response button order used for *concrete/abstract* were counterbalanced between participants. Before the real test, participants completed a practice task with 12 trials (four words of each category).

Post-Test Hearing Assessment

All participants' hearing was assessed post-test by means of fixed-frequency Békésy audiometry estimating their pure tone hearing thresholds for frequencies 250, 500, 1000, 2000, 4000, and 8000 Hz. The audiometry was carried out using a personal computer with an internal Realtek AC97 soundcard (16 bits/44.1 kHz) and a pair of circumaural sound-attenuating Sennheiser HDA 200 earphones. A custom-made computer program (Brännström & Grenner, 2008a; 2008b) generated and presented all stimuli and recorded the participants' responses. The pure-tone stimuli generation and the calibration of the set-up was in accordance with ISO 389-8 (ISO, 2004) and the complete set-up was calibrated using a Brüel and Kjaer 2231 sound level meter with a 4134 microphone in a 4153 artificial ear according to IEC 60318-1 (1998) and IEC 60318-2 (1998). The stimuli used were pulsed pure tones. The pure tones were gated on during 240 ms including 20 ms rise and fall times with a 160 ms silent interval between presentations. Seventy-five presentations were used per frequency. The rate of the intensity change was 2.5 dB per second. The arithmetic mean of all reversals of the individual frequencies was used to calculate the hearing threshold at each frequency.

Post-Test Questionnaires and Emotional Word Ratings

Following the dichotic listening test, all participants completed two questionnaires. The first one included ratings on five-point scales of the difficulty of identifying words and the difficulty of making the semantic judgments, as well as questions about the participants' strategies for performing the task. For example, they were asked to decribe in their own words what they based their *abstract/concrete* classifications on, to give some examples of words that were easy versus difficult to classify, and whether they felt that they attended to each ear equally. The second questionnaire included demographic information such as e.g. age, sex and regional dialect, as well as the revised version of the Edinburgh Handedness scale (Oldfield, 1971). Finally, each participant rated all testwords used in the dichotic listening experiment as to their degree of emotional arousal on a seven-point scale. The words and the rating scale were presented visually in random order on a personal computer with a Dell SE177FPf 17′ screen using E-prime ver. 2.0. Participants were instructed that words that evoked very strong emotional arousal should be given scores at the highest end of the scale, whereas words that were deemed to be completely neutral as regards emotional arousal should be given the lowest score. There was no time limit for responding, although the instructions emphasized that word ratings should be made based on the first impression.

Determining Right Ear Advantage

In order to determine whether participants processed words significantly faster when they were presented to the right ear, the response time data from the left and right ear for each participant were compared by means of independent samples t-tests. Of the 30 participants originally included based on their right-handedness, 18 showed a significant REA in their response times. Of the remaining 12 participants, 8 had no significant advantage for either ear, and 3 showed an advantage for the left ear. This non-right ear advantage (NREA) group was not further analyzed. The t-test results are summarised in Appendix F.

Statistical Analysis

Comparison of concrete/abstract responses to the different testword categories (SPECIFIC/GENERAL/ABSTRACT/EMOTIONAL) was made with Chi Square tests using Preacher (2001). Response times were analyzed by means of repeated-measures ANOVAs using SPSS. Huynh-Feldt correction of degrees of freedom was applied whenever Mauchly's test indicated violation of the assumption of sphericity.

Results

Response Times

The mean response times from all trials were initially compared with a two-way repeated-measures ANOVA with Ear of presentation and Testword category as independent variables. The results are shown in Figure 1 and Table 2. Main effects were found for Ear, $F(1, 17) = 170.894$, $p < .001$, as well as Testword category,

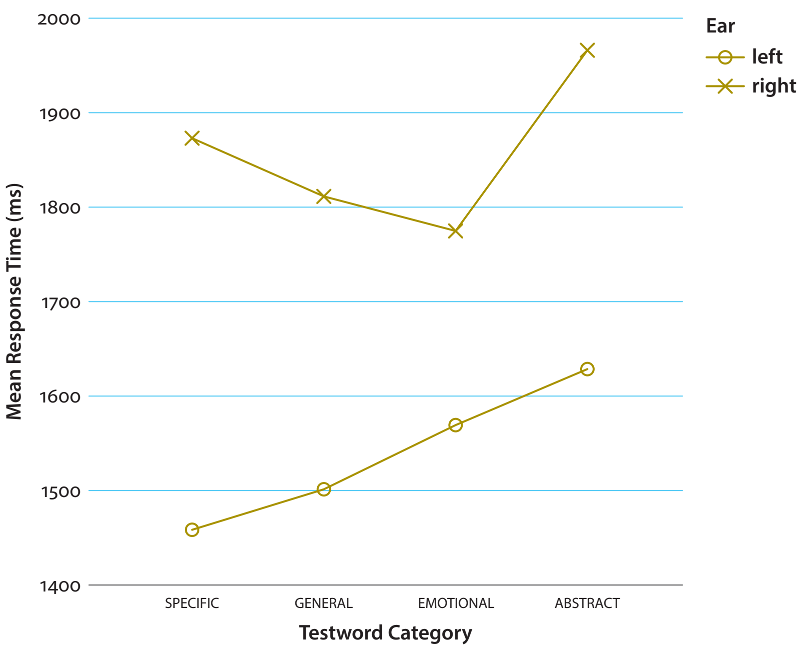


Figure 1. Mean response times (ms) for each testword category and ear.

Table 2. Mean response times (RT) in ms for judging testwords as *Concrete* or *Abstract* for the four testword categories and for right- and left-ear presentation.

		RT /ear (ms)		Difference (ms)
		left	right	
Testword category	SPECIFIC	1873	1458	415
	GENERAL	1811	1501	310
	EMOTIONAL	1775	1569	206
	ABSTRACT	1966	1629	337

$F(3, 15) = 10.060$, $p = .001$. In addition, there was a significant interaction of Ear and Testword, $F(3, 15) = 3.465$, $p = .043$.

Follow-up one-way repeated-measures ANOVAs were carried out for each ear of presentation separately. The ANOVA conducted on the response times for right-ear presentation yielded a significant effect of testword type ($F(3, 15) = 5.280$, $p = .011$). Post hoc Sidak tests revealed that the processing of SPECIFIC testwords gave rise to significantly shorter response times compared to both EMOTIONAL ($p = .021$) and ABSTRACT ($p = .004$) testwords. GENERAL testwords yielded significantly shorter response times compared to ABSTRACT testwords only

(p = .016). There were no significant differences in response times between EMOTIONAL and ABSTRACT words (p = .409), SPECIFIC and GENERAL words (p = .316), or GENERAL and EMOTIONAL words (p = .384). In the response time data from the left-ear presentation, there was also a significant effect of testword type ($F(3, 15)$ = 6.951, p = .004). Post hoc Sidak tests showed that when presented to the left ear, ABSTRACT testwords gave rise to significantly longer response times than GENERAL (p = .004) and EMOTIONAL (p = .022) testwords, but ABSTRACT words did not differ significantly in response times from SPECIFIC testwords (p = .441).

Semantic Classifications

The distribution of *abstract/concrete* classifications for the four testword categories are shown in Figure 2 and Table 3. Statistical analysis showed that words were classified as *concrete* significantly more often than *abstract* if they belonged to the SPECIFIC (e.g. *soup*) (χ^2 = 300.255, $p < .001$, $df = 1$) as well as GENERAL (e.g. *food*) (χ^2 = 207.253, $p < .001$, $df = 1$) testword categories. However, a comparison of the number of SPECIFIC versus GENERAL words which were categorized as *abstract* revealed that a significantly greater number of GENERAL words were judged as *abstract* (χ^2 = 8.377, $p < .01$, $df = 1$). Comparisons involving ABSTRACT (e.g. *task*)

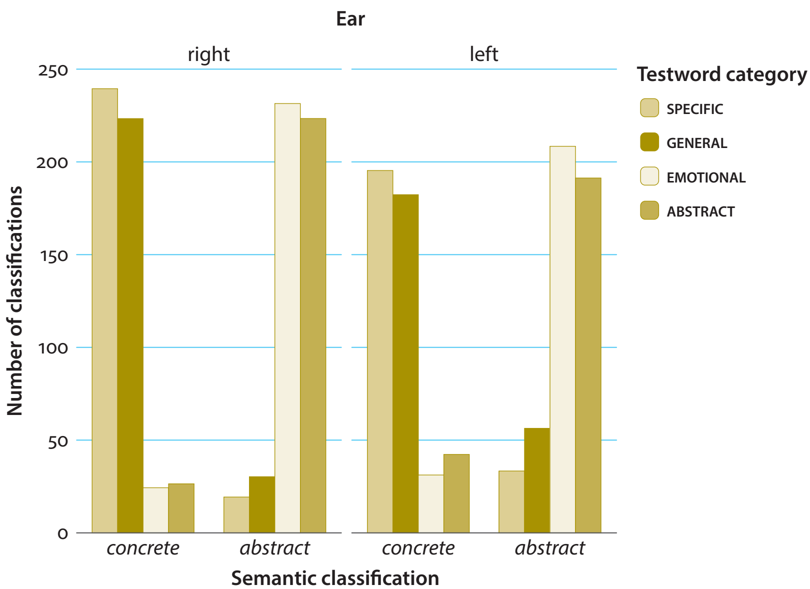


Figure 2. Distribution of semantic classifications of the four testword categories for right- and left-ear presentations.

Table 3. Results for semantic classification of all testword trials.

		Semantic classification		Total
		Concrete	*Abstract*	
Testword category	SPECIFIC	434	52	486
	GENERAL	405	86	491
	EMOTIONAL	55	439	494
	ABSTRACT	68	414	482
Total		962	991	1953

and EMOTIONAL words (e.g. *joy*) showed that testwords from both categories were classified as *abstract* more often than *concrete* (abstract: ($\chi^2 = 248.373$, $p < .001$, $df = 1$; emotional: ($\chi^2 = 298.494$, $p < .001$, $df = 1$).

Discussion

Response Times (RT)

In the response time analysis, an interaction of ear and wordtype was found. For right-ear presentation of testwords, there was a gradual increase in RT as the imageability level decreased from SPECIFIC to ABSTRACT: SPECIFIC–GENERAL–EMOTIONAL–ABSTRACT (see Figure 1). Thus, the lower the imageability values, and the smaller the degree to which words referred to something "visible and touchable" (as was specified in the task instructions), the longer the response times. This is in agreement with the often observed 'concreteness effect' described by Paivio (1990), i.e. that high imageability facilitates word processing. The differences were significant for ABSTRACT testwords compared to SPECIFIC and GENERAL testwords, and for EMOTIONAL testwords compared to the SPECIFIC testwords.

When testwords were presented to the left ear/RH, EMOTIONAL testwords yielded the fastest RTs (Figure 1). This effect can be seen as reflecting emotional words' association with affective information in the RH, in line with e.g. Ely et al. (1989). It is also noteworthy that for left-ear presentation, EMOTIONAL words differed significantly only from ABSTRACT words in their response times. This adds further support for the finding that abstract words with high and low affective content are processed differently (Altarriba & Bauer, 2004; Altarriba, Bauer, & Benvenuto, 1999; Kousta et al., 2011).

However, the SPECIFIC testwords presented to the left ear/RH yielded long RTs which were not significantly different from those of ABSTRACT testwords. This is to be compared to the right-ear presentation, where SPECIFIC and ABSTRACT words were at opposite ends of the RT-interval. Thus, the predictions of the present study regarding SPECIFIC words were supported for right-ear/LH presentation, but not for left-ear/RH presentation. The predictions were based on those of Ely et al. (1989), i.e. that concrete words activate the RH to a greater degree because of their highly imageable semantic content, as well as the finding of Laeng et al. (2003) that picture naming for specific meaning levels involved more RH processing. In contrast, in the present study, SPECIFIC words were the testword type that had the largest difference in response times for left-ear/RH and right-ear/LH presentation.

A possible explanation for this result might be that the RH is specialized in global processing, whereas the LH is specialized in the processing of local details. For example, when processing an image of a global letter shape consisting of many small letters (Navon, 1977), it has been observed that focusing on the local features activates the LH more than the RH, whereas the global shape activates the RH to a greater degree than the LH (Fink, Halligan, Marshall, Frith, Frackowiak, & Dolan, 1996; Fink, Marshall, & Halligan, 2000; Han, Weaver, Murray, Kang, & Yund, 2002). Further supporting this division, investigations of the ability to draw previously presented images from memory have shown that patients with LH lesions tend to replicate the global shape, but omit details, whereas patients with RH lesions replicate details, omitting the overall shape (Robertson & Lamb, 1991).

If the neural processes involved in these differences in processing shapes versus details are also present to some degree in the processing of word meanings, differences in the degree of visual semantic detail associated with words' referents could also be expected to give rise to similar hemispheric differences. The processing of SPECIFIC words associated with detailed visual information (e.g. *carrot*), might then be expected to be more LH lateralized. Such an explanation is also in agreement with the results from a semantic analysis of oral descriptions of word meanings produced by a participant with anomia due to left occipital lesions (Mårtensson et al., 2014). This participant had problems with describing the meanings of highly specific nouns, and in his descriptions, fine-grained details about these nouns were most often omitted, whereas more abstract information as well as words at GENERAL levels (e.g. *thing*, *food*) were provided. Attending to focal details also has been found to selectively activate the left inferior occipital cortex using the Navon stimuli, whereas global attention in the same study was associated with right-hemisphere activation (Fink et al., 1996).

Semantic Judgments

Results from the semantic classification task showed that the majority of words from the EMOTIONAL and ABSTRACT testword categories were judged to be *abstract*, whereas most words belonging to the GENERAL and SPECIFIC categories were judged as being *concrete* (Table 3, Figure 2). These results are in agreement with the fact that imageability ratings were at the high end of the scale for the SPECIFIC and GENERAL testwords used in the study, and at the lower end for the EMOTIONAL and ABSTRACT testwords. Furthermore, GENERAL words (e.g. *mat* 'food') were found to be categorized as *abstract* significantly more often than SPECIFIC words (e.g. *soppa* 'soup'), as might be predicted by the difference in concreteness (imageability) between these two levels of semantic specificity.

As regards the EMOTIONAL testwords, both their imageability and emotional arousal values were higher than those of the ABSTRACT words, suggesting that they are associated with sensory as well as affective experiential information. This raised the expectancy that emotional words would be judged as *concrete* to a greater extent than abstract words. This was, however, not the case. Instead, a large proportion of the words of the EMOTIONAL testword category were judged as being *abstract* (see Table 3). This was the case despite the fact that emotionality was not included in the definition of *abstract* words given in the instructions, which only emphasized their referents' lack of visible and touchable characteristics. Participants also frequently reported in the post-test questionnaire that if the word had emotional content, they considered it to be *abstract*. One possible explanation for this is that it reflects schoolbook definitions, where words for emotions are often used to exemplify abstract words. The learned strategy to judge words with emotional content as *abstract* might then have sometimes overruled any influence from imageability effects during decision-making. The fact that the word categories SPECIFIC, GENERAL, EMOTIONAL and ABSTRACT were compared using a task where the participants were required to explicitly categorize the stimuli as *abstract/concrete* might have magnified or diminished some effects. For example, focusing on sensory (e.g. visual and tangible) features of words as mentioned in the instructions might have made the participants less likely to activate e.g. affective information. Perhaps the RT effect of left-ear/RH presentation that was found for EMOTIONAL words would have been even more pronounced if the focus had not been on just deciding whether or not the referent was something that could be seen or touched. Future studies could no doubt benefit from using a task where the responses are not related to the stimulus categories, e.g. by having test persons make decisions about word familiarity.[3]

3. We would like to thank the editors for drawing our attention to this issue.

General Discussion

The results from the present dichotic listening study increase our understanding of the division of labour between the right and left hemispheres in the processing of word meaning. The results show clear differences in the speed of processing between lexical semantic categories. Although EMOTIONAL words, as compared to the other testword types, were processed relatively faster when presented to the left ear, as expected on the basis of previous studies, this was not the case for SPECIFIC words. This may indicate that words of the SPECIFIC testword category were classified based on activation of visual and other sensory features, rather than more global mental images, and that this led to differences in hemispheric activation similar to those found by e.g. Fink et al. (1996) and Robertson and Lamb (1991).

Given that the task in the present study was rather complex and yielded long overall response times, there may be early differences in semantic processing which were not captured using the present method. Possible different hemispheric contributions to word meaning processing might be revealed using methods with more fine-grained temporal resolution, for example EEG (Bayazıt, Öniz, Hahn, Güntürkün, & Özgören, 2009; Yasin, 2007). Further investigations comparing the processing of these different lexical categories could benefit from using such methods and thus make it possible to study semantic processing on a more detailed level.

Acknowledgements

This research has been supported by grants 421-2004-8918 and 349-2007-8695 from the Swedish Research Council. We also wish to thank the Humanities Lab at Lund University, where the experiment was carried out.

References

Altarriba, J., Bauer, L. M., & Benvenuto, C. (1999). Concreteness, context availability, and imageability ratings and word associations for abstract, concrete, and emotion words. *Behavior Research Methods, Instruments, & Computers* 31>, 578–602. DOI: 10.3758/BF03200738

Altarriba, J., & Bauer, L. M. (2004). The distinctiveness of emotion concepts: A comparison between emotion, abstract, and concrete words. *The American Journal of Psychology*, 117(3), 389–410. DOI: 10.2307/4149007

Bayazıt, O., Öniz, A., Hahn, C., Güntürkün, O., & Özgören, M. (2009). Dichotic listening revisited: Trial-by-trial ERP analyses reveal intra- and interhemispheric differences. *Neuropsychologia*, 47 (2), 536–545. DOI: 10.1016/j.neuropsychologia.2008.10.002

Binder, J. R., Westbury, C., McKiernan, K. A., Possing, E. T., & Medler, D. A. (2005). Distinct brain systems for processing concrete and abstract concepts. *Journal of Cognitive Neuroscience*, 17 (6), 905–917. DOI: 10.1162/0898929054021102

Borod, J. C., Andelman, F., Obler, L. K., Tweedy, J. R., & Wilkowitz, J. (1992). Right hemisphere specialization for the identification of emotional words and sentences: Evidence from stroke patients. *Neuropsychologia*, 30 (9), 827–844. DOI: 10.1016/0028-3932(92)90086-2

Brännström, K. J., & Grenner, J. (2008a). Long-term measurement of binaural intensity matches and pitch matches. *I. Normal hearing. International Journal of Audiology*, 47 (2), 59–66. DOI: 10.1080/14992020701643826

Brännström, K. J, & Grenner, J. (2008b). Clinical application of long-term intensity and pitch matches in fluctuating low-frequency hearing loss. *International Journal of Audiology*, 47 (7), 412–419. DOI: 10.1080/14992020801991729

Buchanan, T. W., Lutz, K., Mirzazade, S., Specht, K., Shah, N. J., Zilles, K., & Jäncke, L. (2000). Recognition of emotional prosody and verbal components of spoken language: an fMRI study. *Cognitive Brain Research*, 9 (3), 227–238. DOI: 10.1016/S0926-6410(99)00060-9

Coltheart, M. (1981). The MRC psycholinguistic database. *The Quarterly Journal of Experimental Psychology Section A*, 33 (4), 497–505. DOI: 10.1080/14640748108400805

Crutch, S. J., & Warrington, E. K. (2003). Preservation of propositional speech in a pure anomic: The importance of an abstract vocabulary. *Neurocase*, 9 (6), 465–481. DOI: 10.1076/neur.9.6.465.29373

Ely, P. W., Graves, R. E., & Potter, S. M. (1989). Dichotic listening indices of right hemisphere semantic processing. *Neuropsychologia*, 27 (7), 1007–1015. DOI: 10.1016/0028-3932(89)90076-6

Ejerhed, E., Källgren, G., Wennstedt, O., & Åström, M. 1992. The linguistic annotation system of the Stockholm-Umeå corpus roject. *Tech. rep*. 33, Department of General Linguistics, Umeå University, Umeå, Sweden.

Fink, G. R., Halligan, P. W., Marshall, J. C., Frith, C. D., Frackowiak, R. S. J., & Dolan, R. J. (1996). Where in the brain does visual attention select the forest and the trees? *Nature*, 382 (6592), 626–628. DOI: 10.1038/382626a0

Fink, G. R., Marshall, J. C., & Halligan, P. W. (2000). Neuronal activity in early visual areas during global and local processing: A comment on Heinze, Hinrichs, Scholz, Burchert, and Mangun. *Journal of Cognitive Neuroscience*, 12 (2), 355–356. DOI: 10.1162/089892900562039

Han, S., Weaver, J. A., Murray, S. O., Kang, X., & Yund, E. W. (2002). Hemispheric Asymmetry in Global/Local Processing: Effects of stimulus position and spatial frequency. *NeuroImage*, 17, 1290–1299. DOI: 10.1006/nimg.2002.1255

Hauk, O., & Pulvermüller, F. (2004). Neurophysiological distinction of action words in the fronto-central cortex. *Human Brain Mapping*, 21 (3), 191–201. DOI: 10.1002/hbm.10157

Hickok, G., & Poeppel, D. (2007). The cortical organization of speech processing. *Nature Reviews Neuroscience*, 8 (5), 393–402. DOI: 10.1038/nrn2113

Hugdahl, K. (2000). Lateralization of cognitive processes in the brain. *Acta Psychologica*, 105 (2–3), 211–235. DOI: 10.1016/S0001-6918(00)00062-7

Khader, P. H., Jost, K., Mertens, M., Bien, S., & Rösler, F. (2010). Neural correlates of generating visual nouns and motor verbs in a minimal phrase context. *Brain Research*, 1318 (C), 122–132. DOI: 10.1016/j.brainres.2009.12.082

Kimura, D. (1967). Functional Asymmetry of the brain in dichotic listening. *Cortex*, 3 (2), 163–178. DOI: 10.1016/S0010-9452(67)80010-8

Kousta, S.-T., Vinson, D. P., & Vigliocco, G. (2009). Emotion words, regardless of polarity, have a processing advantage over neutral words. *Cognition*, 112 (3), 473–481. DOI: 10.1016/j.cognition.2009.06.007
Kousta, S.-T., Vigliocco, G., Vinson, D. P., Andrews, M., & Del Campo, E. (2011). The representation of abstract words: Why emotion matters. *Journal of Experimental Psychology: General*, 140 (1), 14–34. DOI: 10.1037/a0021446
Laeng, B., Zarrinpar, A., & Kosslyn, S. M. (2003). Do separate processes identify objects as exemplars versus members of basic-level categories? Evidence from hemispheric specialization. *Brain and Cognition*, 53 (1), 15–27. DOI: 10.1016/S0278-2626(03)00184-2
Ley, R. G., & Bryden, M. P. (1982). A dissociation of right and left hemispheric effects for recognizing emotional tone and verbal content. *Brain and Cognition*, 1 (1), 3–9. DOI: 10.1016/0278-2626(82)90002-1
Mårtensson, F., Roll, M., Apt, P., & Horne, M. (2011). Modeling the meaning of words: Neural correlates of abstract and concrete noun processing. *Acta Neurobiologiae Experimentalis*, 71, 455–478.
Mårtensson, F., Roll, M., Lindgren, M., Apt, P., & Horne, M. (2014). Sensory-specific anomic aphasia following left occipital lesions: Data from free oral descriptions of concrete word meanings. *Neurocase*, 20 (2), 192–207. DOI: 10.1080/13554794.2012.741258
McFarland, K., McFarland, M. L., Bain, J. D., & Ashton, R. (1978). Ear differences of abstract and concrete word recognition. *Neuropsychologia*, 16, 555–561. DOI: 10.1016/0028-3932(78)90083-0
Navon, D. (1977). Forest before trees: The precedence of global features in visual perception. *Cognitive Psychology*, 9 (3), 353–383. DOI: 10.1016/0010-0285(77)90012-3
Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychologia*, 9(1), 97–113. DOI: 10.1016/0028-3932(71)90067-4
Oliveira, J., Perea, M. V., Ladera, V., & Gamito, P. (2013). The roles of word concreteness and cognitive load on interhemispheric processes of recognition. *Laterality: Asymmetries of Body, Brain and Cognition*, 18 (2), 203–215. DOI: 10.1080/1357650X.2011.649758
Paivio, A. (1990). *Mental representations*. Oxford: Oxford University Press. DOI: 10.1093/acprof:oso/9780195066661.001.0001
Paivio, A. (2010). Dual coding theory and the mental lexicon. *The Mental Lexicon*, 5 (2), 205–230. DOI: 10.1075/ml.5.2.04pai
Preacher, K. J. (2001, April). Calculation for the chi-square test: An interactive calculation tool for chi-square tests of goodness of fit and independence [Computer software]. Available from http://quantpsy.org.
Prior, M. R., Cumming, G., & Hendy, J. (1984). Recognition of abstract and concrete words in a dichotic listening paradigm. *Cortex*, 20 (1), 149–157. DOI: 10.1016/S0010-9452(84)80032-5
Pujol, J., Deus, J., Losilla, J. M., & Capdevila, A. (1999). Cerebral lateralization of language in normal left-handed people studied by functional MRI. *Neurology*, 52 (5), 1038–1038. DOI: 10.1212/WNL.52.5.1038
Robertson, L. C., & Lamb, M. R. (1991). Neuropsychological contributions to theories of part/whole organization. *Cognitive Psychology*, 23, 299–330. DOI: 10.1016/0010-0285(91)90012-D
Roll, M., Mårtensson, F., Sikström, S., Apt, P., Arnling-Bååth, R., & Horne, M. (2012). Atypical associations to abstract words in Broca's aphasia. *Cortex*, 48 (8), 1068–1072. DOI: 10.1016/j.cortex.2011.11.009

Rosch, E., Mervis, C. B., Gray, W. D., Johnson, D. M., & Boyes-Braem, P. (1976). Basic objects in natural categories. *Cognitive Psychology*, 8 (3), 382–439. DOI: 10.1016/0010-0285(76)90013-X
Rutten, G. J. M., Ramsey, N. F., van Rijen, P. C., Alpherts, W. C., & van Veelen, C. W. M. (2002). fMRI-determined language ateralization in patients with inilateral or mixed language dominance according to the wada test. *NeuroImage*, 17 (1), 447–460. DOI: 10.1006/nimg.2002.1196
Sabsevitz, D. S., Medler, D. A., Seidenberg, M., & Binder, J. R. (2005). Modulation of the semantic system by word imageability. *NeuroImage*, 27 (1), 188–200. DOI: 10.1016/j.neuroimage.2005.04.012
Sandberg, C., & Kiran, S. (2014). Analysis of abstract and concrete word processing in persons with aphasia and age-matched neurologically healthy adults using fMRI. *Neurocase*, 20 (4), 361–388. DOI: 10.1080/13554794.2013.770881
Wada, J., & Rasmussen, T. (1960). Intracarotid injection of sodium amythal for the lateralization of cerebral speech dominance: Experimental and clinical observations. *Journal of Neurosurgery*, 17, 266–282. DOI: 10.3171/jns.1960.17.2.0266
Warrington, E. K. (1975). The selective impairment of semantic memory. *Quarterly Journal of Experimental Psychology*, 27 (4), 635–657. DOI: 10.1080/14640747508400525
Westbury, C., & Moroschan, G. (2009). Imageability x phonology interactions during lexical access: Effects of modality, phonological neighbourhood, and phonological processing efficiency. *The Mental Lexicon*, 4 (1), 115–145. DOI: 10.1075/ml.4.1.05wes
Westbury, C. F., Shaoul, C., Hollis, G., Smithson, L., Briesemeister, B. B., Hofmann, M. J., & Jacobs, A. M. (2013). Now you see it, now you don't: On emotion, context, & the algorithmic prediction of human imageability judgments. *Frontiers in Psychology*, 4, 991. DOI: 10.3389/fpsyg.2013.00991
Yasin, I. (2007). Hemispheric differences in processing dichotic meaningful and non-meaningful words. *Neuropsychologia*, 45 (12), 2718–2729. DOI: 10.1016/j.neuropsychologia.2007.04.009

Appendix A. English Translations of Stimuli Words

SPECIFIC		GENERAL		ABSTRACT		EMOTIONAL	
Swedish	**English**	**Swedish**	**English**	**Swedish**	**English**	**Swedish**	**English**
fågel	bird	djur	animal	frihet	freedom	kärlek	love
banan	banana	frukt	fruit	råd	advice	glädje	joy
träd	tree	växt	plant	rykte	rumor	oro	worry
torg	market	plats	place	löfte	promise	sorg	sorrow
såg	saw	verktyg	tool	moral	moral	lycka	luck
mangel	mangle	maskin	machine	plikt	duty	mod	courage
dator	computer	pryl	gadget	datum	date	lust	lust
bil	car	fordon	vehicle	stil	style	längtan	yearning
bord	table	möbel	furniture	svar	answer	humor	humour
regn	rain	väder	weather	prestige	prestige	skräck	horror
byxa	trousers	kläder	clothes	mognad	maturity	tröst	comfort

SPECIFIC		GENERAL		ABSTRACT		EMOTIONAL	
Swedish	**English**	**Swedish**	**English**	**Swedish**	**English**	**Swedish**	**English**
granit	granite	sten	stone	uppgift	task	skam	shame
kvinna	woman	person	person	magi	magic	ilska	anger
pistol	pistol	vapen	weapon	visdom	wisdom	sjukdom	disease
sommar	summer	årstid	season	påhitt	idea	lättnad	relief
Jorden	Earth	planet	planet	ordning	order	chock	shock
kaffe	coffee	dryck	beverage	tanke	thought	framgång	success
vatten	water	vätska	fluid	arv	heritage	hat	hatred
tårta	cake	bakverk	pastry	krav	demand	kris	crisis
morot	carrot	grönsak	vegetable	term	term	förakt	contempt
hus	house	byggnad	building	rutin	routine	fest	party
peppar	pepper	krydda	spice	bevis	proof	kaos	chaos
fyrkant	square	form	shape	fas	phase	död	death
vals	waltz	dans	dance	tendens	tendency	spänning	excitement
spade	spade	redskap	tool	behov	need	fördel	advantage
frisör	hairdresser	yrke	occupation	metod	method	krig	war
orm	snake	reptil	reptile	brist	lack	skada	harm
bi	bee	kryp	bug	fakta	fact	liv	life
boll	ball	grej	thing	mängd	amount	problem	problem
soppa	soup	mat	food	avsikt	intent	vänskap	friendship

Appendix B. Word-Pseudoword Pairs

SPECIFIC		GENERAL		ABSTRACT		EMOTIONAL	
W	**PsW**	**W**	**PsW**	**W**	**PsW**	**W**	**PsW**
fågel	figar	djur	djam	frihet	frugit	kärlek	kjoldig
banan	betak	frukt	frelk	råd	rul	glädje	glamra
träd	tram	växt	vird	rykte	rinko	oro	one
torg	terp	plats	plunk	löfte	lebka	sorg	silt
såg	sun	verktyg	vongter	moral	mödek	lycka	lonte
mangel	mudar	maskin	mirgol	plikt	plesk	mod	mis
dator	doger	pryl	pruk	datum	duner	lust	lygd
bil	buf	fordon	finpud	stil	stöm	längtan	lestor
bord	birn	möbel	miges	svar	svel	humor	hivel
regn	ralp	väder	vulan	prestige	prinkus	skräck	skrum
byxa	bonta	kläder	klosit	mognad	milklur	tröst	trenk
granit	grutan	sten	stof	uppgift	unnsang	skam	skod
kvinna	kvalle	person	pufid	magi	murö	ilska	isbre
pistol	purtas	vapen	venit	visdom	valnad	sjukdom	sjårbal
sommar	sännas	årstid	åsprag	påhitt	purall	lättnad	lasskin
Jorden	jendal	planet	plefir	ordning	ojtrask	chock	skynn

SPECIFIC		GENERAL		ABSTRACT		EMOTIONAL	
W	PsW	W	PsW	W	PsW	W	PsW
kaffe	konni	dryck	dröng	tanke	tespa	framgång	frölkan
vatten	verrut	vätska	vanple	arv	ant	hat	hås
tårta	tille	bakverk	bulting	krav	krip	kris	krul
morot	mekor	grönsak	gromdis	term	tann	förakt	felonk
hus	hek	byggnad	bannbal	rutin	rybod	fest	farp
peppar	pottig	krydda	kralle	bevis	bamal	kaos	keam
fyrkant	falkons	form	fump	fas	fud	död	dib
vals	vilk	dans	dilt	tendens	talbind	spänning	spallest
spade	spöni	redskap	runtrok	behov	bosik	fördel	filpån
frisör	franål	yrke	ymla	metod	miner	krig	kryd
orm	olk	reptil	riskon	brist	brall	skada	skobe
bi	bå	kryp	kreb	fakta	filde	liv	lad
boll	batt	grej	grit	mängd	malbs	problem	priglot
soppa	siffe	mat	miv	avsikt	arpenk	vänskap	vurspon

Appendix C. Words with Values for Frequency, Imageability and Emotional Arousal

Swedish	English	Wordtype	Frequency	Imageability	Emotional arousal
banan	banana	SPECIFIC	5	644	180
bi	bee	SPECIFIC	4	623	213
bil	car	SPECIFIC	371	638	197
boll	ball	SPECIFIC	17	622	190
bord	table	SPECIFIC	134	582	130
byxa	trousers	SPECIFIC	23	630	150
dator	computer	SPECIFIC	212	–	197
frisör	hairdresser	SPECIFIC	2	–	170
fyrkant	square	SPECIFIC	3	610	127
fågel	bird	SPECIFIC	68	614	233
granit	granite	SPECIFIC	1	–	153
hus	house	SPECIFIC	354	606	223
Jorden	Earth	SPECIFIC	1	580	417
kaffe	coffee	SPECIFIC	93	618	273
kvinna	woman	SPECIFIC	573	626	440
mangel	mangle	SPECIFIC	0	–	160
morot	carrot	SPECIFIC	15	577	170
orm	snake	SPECIFIC	7	627	307
peppar	pepper	SPECIFIC	3	587	177
pistol	pistol	SPECIFIC	24	613	463

Swedish	English	Wordtype	Frequency	Imageability	Emotional arousal
regn	rain	SPECIFIC	44	618	300
sommar	summer	SPECIFIC	165	618	447
soppa	soup	SPECIFIC	18	604	170
spade	spade	SPECIFIC	2	538	130
såg	saw	SPECIFIC	21	531	153
torg	market	SPECIFIC	44	583	187
träd	tree	SPECIFIC	121	622	243
tårta	cake	SPECIFIC	5	624	250
vals	waltz	SPECIFIC	3	524	257
vatten	water	SPECIFIC	422	632	280
bakverk	pastry	GENERAL	2	–	227
byggnad	building	GENERAL	83	578	160
dans	dance	GENERAL	75	510	387
djur	animal	GENERAL	218	575	300
dryck	beverage	GENERAL	30	565	210
fordon	vehicle	GENERAL	24	593	173
form	shape	GENERAL	512	471	190
frukt	fruit	GENERAL	25	587	203
grej	thing	GENERAL	20	358	143
grönsak	vegetable	GENERAL	1	598	180
kläder	clothes	GENERAL	91	629	240
krydda	spice	GENERAL	8	592	197
kryp	bug	GENERAL	3	–	247
maskin	machine	GENERAL	66	575	187
mat	food	GENERAL	151	539	333
möbel	furniture	GENERAL	20	588	150
person	person	GENERAL	555	562	253
planet	planet	GENERAL	9	578	327
plats	place	GENERAL	443	377	200
pryl	gadget	GENERAL	3	–	153
redskap	tool	GENERAL	31	391	160
reptil	reptile	GENERAL	0	579	227
sten	stone	GENERAL	115	612	153
vapen	weapon	GENERAL	87	546	510
verktyg	tool	GENERAL	45	538	173
väder	weather	GENERAL	85	537	300
vätska	fluid	GENERAL	26	–	177
växt	plant	GENERAL	74	605	200
yrke	occupation	GENERAL	46	406	250
årstid	season	GENERAL	18	495	317
arv	heritage	ABSTRACT	41	–	300
avsikt	intent	ABSTRACT	64	286	310
behov	need	ABSTRACT	245	327	400

Swedish	English	Wordtype	Frequency	Imageability	Emotional arousal
bevis	proof	ABSTRACT	54	339	320
brist	lack	ABSTRACT	128	302	370
datum	date	ABSTRACT	18	501	167
fakta	fact	ABSTRACT	6	302	230
fas	phase	ABSTRACT	30	319	170
frihet	freedom	ABSTRACT	83	437	610
krav	demand	ABSTRACT	240	–	503
löfte	promise	ABSTRACT	27	320	477
magi	magic	ABSTRACT	6	458	387
metod	method	ABSTRACT	192	304	180
mognad	maturity	ABSTRACT	9	–	357
moral	moral	ABSTRACT	25	341	477
mängd	amount	ABSTRACT	185	316	170
ordning	order	ABSTRACT	153	352	303
plikt	duty	ABSTRACT	21	346	467
prestige	prestige	ABSTRACT	9	394	463
påhitt	idea	ABSTRACT	2	319	283
rutin	routine	ABSTRACT	43	341	317
rykte	rumour	ABSTRACT	36	353	373
råd	advice	ABSTRACT	100	352	303
stil	style	ABSTRACT	78	464	293
svar	answer	ABSTRACT	192	368	250
tanke	thought	ABSTRACT	306	348	393
tendens	tendency	ABSTRACT	54	261	243
term	term	ABSTRACT	82	368	153
uppgift	task	ABSTRACT	465	410	270
visdom	wisdom	ABSTRACT	5	381	397
chock	shock	EMOTIONAL	14	471	553
död	death	EMOTIONAL	332	498	643
fest	party	EMOTIONAL	41	596	430
framgång	success	EMOTIONAL	92	443	467
förakt	contempt	EMOTIONAL	18	364	597
fördel	advantage	EMOTIONAL	121	292	283
glädje	joy	EMOTIONAL	86	533	613
hat	hatred	EMOTIONAL	16	417	650
humor	humour	EMOTIONAL	24	462	497
ilska	anger	EMOTIONAL	17	488	597
kaos	chaos	EMOTIONAL	18	464	520
krig	war	EMOTIONAL	131	551	593
kris	chrisis	EMOTIONAL	55	375	597
kärlek	love	EMOTIONAL	117	569	660
liv	life	EMOTIONAL	685	482	517
lust	lust	EMOTIONAL	43	444	563

Swedish	English	Wordtype	Frequency	Imageability	Emotional arousal
lycka	luck	EMOTIONAL	51	533	637
längtan	yearning	EMOTIONAL	35	368	607
lättnad	relief	EMOTIONAL	14	432	530
mod	courage	EMOTIONAL	26	440	540
oro	worry	EMOTIONAL	58	422	583
problem	problem	EMOTIONAL	474	411	443
sjukdom	disease	EMOTIONAL	140	487	510
skada	harm	EMOTIONAL	140	443	423
skam	shame	EMOTIONAL	22	419	593
skräck	horror	EMOTIONAL	23	545	630
sorg	sorrow	EMOTIONAL	51	429	643
spänning	excitement	EMOTIONAL	49	452	553
tröst	comfort	EMOTIONAL	22	421	530
vänskap	friendship	EMOTIONAL	14	535	577

Appendix D. Instructions

Swedish

Du kommer att få lyssna på riktiga ord och låtsasord som presenteras samtidigt. Det kan ibland vara svårt att höra de riktiga orden, men det finns ett riktigt ord med i alla ljud som spelas upp.

Din uppgift är att urskilja de riktiga orden och bedöma om de är konkreta eller abstrakta. Konkreta ord är saker man kan se och ta på, abstrakta ord är tvärtom inte synbara och påtagliga. Gör dina bedömningar baserat på ditt första intryck och svara så snabbt som möjligt. Tryck "K" om ordet du hör är konkret och "A" om det är abstrakt. Försök svara även om du inte är helt säker. Om du inte svarar fortsätter experimentet automatiskt till nästa ord.

Innan det riktiga experimentet får du prova med några övningsexempel. Tryck på valfri tangent för att börja.

English Translation

You will listen to real words and pretend words which are presented simultaneously. It may sometimes be difficult to hear the real words, but there is a real word in every sound that is played.

Your task is to distinguish the real words and decide if they are concrete or abstract. Concrete words are things you can see and touch, abstract words, in contrast, are not visible or tangible. Make your decisions based on your first impression and respond as quickly as possible. Press "K" if the word you hear is concrete and "A" if it is abstract. Try to respond even if you are not entirely certain. If you do not respond, the experiment automatically moves on to the next word.

Before the real experiment starts, you will be given some practice examples. Press any key to start.

Appendix E. Edinburgh Handedness Scale (Revised)

Edinburgh Handedness Inventory (revised)					
Please mark the alternative describing best which hand you would use for each activity					
	Always left	Normally left	No preference	Normally right	Always right
1. Write					
2. Draw					
3. Throw					
4. Scissors					
5. Toothbrush					
6. Knife (without fork)					
7. Spoon					
8. Match (when lighting)					
9. Broom (upper hand)					
10. Open can (lid)					

11. Do you see yourself as right-handed left-handed

Appendix F. Participants Included in the REA and NREA Groups with t-test Results and Laterality Quotients (LQ)

	Subject	RT right ear (ms)		RT left ear (ms)		t(df)	p	LQ
		M	SD	M	SD			
REA	13	1549	489	1980	535	−4.162 (96)	<.001	100
	14	1454	521	1872	569	−4.019(108)	<.001	95
	19	1557	423	1875	487	−3.635(107)	<.001	95
	20	1623	586	1969	500	−3.059(91)	=.003	85
	23	1610	350	1892	397	−3.817(101)	<.001	80
	25	1579	528	1949	537	−3.706(112)	<.001	100
	29	1685	472	2072	461	−4.351(109)	<.001	50
	34	1536	465	1879	469	−3.910(112)	<.001	70
	37	1456	358	1638	441	−2.436(114)	=.016	75
	39	1251	359	1458	412	−2.935(118)	=.004	60
	41	1361	373	1522	449	−2.140(118)	=.034	100
	42	1401	483	1634	335	−2.808(99)	=.006	70
	43	1552	401	1694	283	−2.169(112)	=.032	70
	44	1736	510	2077	512	−3.263(94)	=.002	80

	Subject	RT right ear (ms)		RT left ear (ms)		t(df)	p	LQ
		M	SD	M	SD			
	46	1541	422	2043	488	−5.942(114)	<.001	60
	49	1403	456	1804	423	−4.631(104)	<.001	95
	50	1520	356	1935	477	−5.209(109)	<.001	65
	51	1871	591	2120	453	−2.344(99)	=.021	50
NREA	12	1891	505	1894	576	−0.032(103)	=.975	80
	15	1480	381	1498	388	−0.254(118)	=.800	80
	16	1811	471	1691	371	1.494(109)	=.138	70
	17	1308	364	1371	360	−0.954(118)	=.342	80
LEA	22	1769	517	1558	458	2.208(102)	=.03	90
	24	1540	450	1603	392	−0.813(116)	=.418	85
	26	1567	496	1731	462	−1.821(111)	=.071	75
	28	1802	559	2007	497	−1.847(89)	=.068	100
LEA	35	1600	449	1384	426	2.675(116)	=.009	100
LEA	38	1553	390	1249	374	4.338(117)	<.001	85
	45	1478	456	1403	473	0.875(117)	=.384	75
	47	1272	367	1299	425	−0.371(118)	=.711	75

Corresponding Address

Frida Blomberg
Department of Linguistics and Phonetics
Centre of Languages and Literature
Box 201, 221 00 Lund
Sweden

frida.blomberg@ling.lu.se

Paper IV

Lexical specificity, imageability and emotional arousal modulate the N400 and the N700 during imageability rating and lexical decision tasks

Blomberg F., Roll, M., Lindgren, M. & Horne, M.

Abstract: The event-related potential (ERP) component N400 as well as a later effect, often labeled 'N700' have repeatedly been shown to have increased amplitudes for concrete as compared to abstract words. In addition, pseudowords have been seen to elicit greater N400s than real words. Previous interpretations of the N400 as indexing contextual integration or alternatively, activation of semantic features in long-term memory, do not fully explain the combination of these differences. The present study compared ERP's in the N400 and N700 time-windows for PSEUDOWORDS (e.g. *danalod*) and four noun categories increasingly high in imageability: (SPECIFIC, e.g. *squirrel*, GENERAL, e.g. *animal*, EMOTIONAL, e.g. *happiness* and ABSTRACT, e.g. *tendency*). EEG and response times were measured during a lexical decision (LD) task and an imageability rating (IR) task. In the LD task, N400 amplitudes increased in the order EMOTIONAL < ABSTRACT < GENERAL < SPECIFIC < PSEUDOWORD. A largely similar pattern was found in the IR task as well as in the N700 time-window of both tasks. A possible explanation for this patterning of ERP amplitudes might be that words with larger numbers of associated words in the mental lexicon yield smaller N400s. N400 and N700 effects were found for SPECIFIC-GENERAL test words differing in imageability, and even when they were matched for imageability, providing support for the hypothesis that other factors possibly related to hierarchical semantic relations between concrete noun categories drive the effect. This would be in accordance with the present study's main hypothesis, which assumes that superordinate GENERAL nouns have a larger number of lexical associates than SPECIFIC nouns.

Key words: semantic features, abstract words, concrete words, imageability, emotional arousal, lexical specificity, lexical associates, ERP, response times, N400, N700

1. Introduction

1.1 Concreteness, imageability and lexical specificity

The present study was carried out in order to shed more light on the neurocognitive processing of nouns differing in their degree of concreteness. Using electrophysiological methodology, the study targeted event-related potentials (ERP) patterns in the N400 and N700 time-windows for four noun categories systematically varying in imageability[1]: SPECIFIC (e.g. *carrot*), GENERAL (e.g. *food*), EMOTIONAL (e.g. *love*) and ABSTRACT (e.g. *idea*). These were compared with patterns for PSEUDOWORDS (e.g. *kvup*). N400 and N700 amplitudes have previously been seen to differ systematically for concrete words, abstract words and pseudowords, although no unitary explanation for this pattern has yet been proposed. The present study compared ERP effects for the more fine-grained subdivision of word categories described above and interprets the result taking effects of imageability as well as lexicality into account.

Concrete and abstract words have been suggested to have different cognitive frameworks, with concrete words being organised mainly into taxonomic categories and abstract words being organised by association with other words (Crutch & Warrington, 2005; 2010; Crutch, Connell, & Warrington, 2009). Other models have assumed a qualitative difference between concrete and abstract words, with abstract words being more language-dependent and concrete words associated with additional sensory information (Paivio, 2010). Quantitative differences in terms of the contexts related to abstract and concrete words have also been suggested, proposing stronger contextual associations for concrete words (Schwanenflugel & Shoben, 1983) as well as differences in contextual constraints (Wiemer-Hastings, Krug, & Xu, 2001).

The SPECIFIC and GENERAL noun categories were subject to some extra investigation in the current study. The reason for this focus is that in addition to differences reflected in imageability ratings, they exemplify a central lexical taxonomic relationship 'hyponymy', with the GENERAL nouns constituting superordinate categories (hyperonyms) in relation to the SPECIFIC noun category (hyponyms). This SPECIFIC-GENERAL relation has a central role in models of lexical semantics (Miller &

[1] Imageability (how easily a word gives rise to a sensory experience) is closely related to concreteness (to what degree a word refers to a tangible object) (Gilhooly & Logie, 1980; Paivio, Yuille, & Madigan, 1968). Although not identical (Westbury et al., 2013), imageability and concreteness are highly correlated and often used interchangeably to determine concreteness (Nittono, Suehiro, & Hori, 2002; Sabsevitz, Medler, Seidenberg, & Binder, 2005; Westbury & Moroschan, 2009) and will be used in the same way in the present study.

Fellbaum, 1991; Lyons, 1977) and cognitive organisation (Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976), but has rarely been the focus of electrophysiological studies (Kounios & Holcomb, 1992). An assumption of lexical semantics is that the subordinate concepts in a semantic domain share the features which define the general/superordinate concept, for example that *horse* has all the defining features of *animal* plus features that distinguish horses from other kinds of animals (Miller & Fellbaum, 1991; Rosch et al., 1976). More general nouns are also important for the structuring of discourse, where they are commonly used to refer back to more specific concepts (Ariel, 1990), but not vice versa. This phenomenon can be illustrated by the following example: *My brother bought a German shepard. He just loves the dog* as compared with *My brother bought a dog. He just loves the German shepard.* In other words, the antecedent specific concept is reactivated or, in Ariel's terminology, becomes "accessible" through a superordinate, more general concept. Referring back to an antecedent general concept using a more specific concept creates a less coherent discourse.

Degree of semantic specificity can be expected to be reflected using methods that can capture the strength of the semantic relation a word has to other words in the lexicon (e.g. differences in the N400 ERP). Given the hierarchical semantic relations assumed for concrete words in lexical semantics, general nouns can be expected to have more lexical associations to other concrete nouns than specific nouns do.

Semantic specificity can also be thought to be reflected in concreteness and imageability ratings, given the greater detailed character of referents of more specific nouns; however, there does not seem to be any one-to-one relationship between levels of hierarchical semantic structure and subjective ratings for concreteness and imageability. Rosch & Lloyd (1978) suggested that the 'basic' level of semantic categorisation is the most general level where a mental image corresponding to the class as a whole can be formed. This leads to the prediction that superordinate concrete nouns like *vegetable* would be associated with a lower rating for imageability than a specific noun like *carrot* (which is not true in this particular case: *vegetable* = 598, *carrot* = 577 (Coltheart, 1981)). In stimuli sets in previous studies comparing words at SPECIFIC and GENERAL levels, SPECIFIC nouns have had higher imageability ratings than GENERAL nouns (Blomberg, Roll, Lindgren, Brännström, & Horne, 2015), as well as lower concreteness ratings (Kounios & Holcomb, 1992). Thus, if there were differences in the ERPs elicited by GENERAL and SPECIFIC nouns, it would be interesting to see if such effects varied with degrees of imageability or if they instead could be related to differences in the level of taxonomic categorisation and lexical associations assumed to characterise concrete and abstract words (Crutch et al., 2009; Crutch & Warrington, 2005; 2010).

1.2 Concreteness-related ERP effects: The N400 and N700

1.2.1 N400

The N400 is a negative deflection around 400 ms which is typically less negative-going for more predictable stimuli. This effect has been suggested to reflect either facilitated integration into context or facilitated lexical access due to pre-activation of semantic features in long-term memory and it is likely to be the result of activity from several neural generators (Kutas & Federmeier, 2011; Lau, Phillips, & Poeppel, 2008). The N400 was originally found to be larger for stimuli that are semantically anomalous or unpredictable following a preceding sentence context, such as 'I take coffee with cream and *dog*' (Kutas & Hillyard, 1980). Since then, the N400 has been found to be sensitive to a number of different manipulations. For example, it is attenuated in target words presented following semantically related prime words (Rugg, 1985). It can also be modulated in single word stimuli, based on factors that seem to be related to predictability or ease of processing. For example, infrequent words give rise to larger N400 amplitudes than frequent words and pseudowords yield larger N400s than real words (Kutas & Federmeier, 2000; Lau et al., 2008).

Of particular relevance for the present study is the fact that robust differences in N400 amplitudes have also been found for concrete and abstract words. N400 have repeatedly been shown to be more negative for concrete than abstract words (Barber, Otten, Kousta, & Vigliocco, 2013; Gullick, Mitra, & Coch, 2013; Kounios & Holcomb, 1994; Nittono et al., 2002). This finding is less straightforward to explain in terms of facilitation or predictability, given that the less negative N400 amplitudes for single abstract words would then mean that they are less effortfully processed/more predictable relative to single concrete words. Contrary to this implication, behavioural experiments have consistently shown slower response times and lower accuracy for abstract than concrete words presented in isolation (Paivio, 2010).

It appears contradictory that concrete words are easier to process, yet elicit more negative N400's. A proposed explanation is that the N400 for single concrete nouns is a result of greater activation of semantic features in long-term memory (Barber et al., 2013; Gullick et al., 2013). Following this line of reasoning, the negativity in the N400 time-window reflects a greater activation of semantic features during the lexical access of concrete words. Although this greater feature activation manifests itself as a larger N400, the neural activity can be accompanied by faster and more accurate behavioural responses.

The semantic feature activation account of the N400 encounters problems when trying to explain why N400 amplitudes are more negative for pseudowords than for real words. Arguably, pseudowords should not activate semantic features, since they are not associated with any semantic information and are unlikely to have been previously encountered. However, if the interpretation of the N400 can be related to the processing of word meaning through association of words with other words (Crutch, 2006; Paivio, 1990), then the greater negativity associated with pseudowords can be accounted for by assuming that it is due to the fact that they lack association to any other words.

In at least one ERP study (Kounios & Holcomb, 1992), relatively specific nouns (e.g. *dog*) have been seen to produce more negative amplitudes as compared to more general nouns (e.g. *animal*). They did this with a stimulus set where concreteness was higher for the more general nouns, indicating that the process behind the difference is not related to concreteness. However, as discussed by the authors, another factor which might have contributed to this difference, was that the general, but not the specific stimuli were repeated in the experiment. Also touching upon the factors of specificity and concreteness/imageability, Barber et al. (2013) replicated previously found negative N400 and N700 for concrete as compared to abstract words, despite the fact that they used a stimuli set carefully matched for a number of properties, including imageability. Although lexical specificity was not systematically varied in their design, their concrete stimuli included several of what in the present study are referred to as the GENERAL nouns, e.g. *material* and *weapon*, possibly a result of the relatively low imageability of the set as a whole.

Using a dichotic listening paradigm, Blomberg et al. (2015) compared SPECIFIC and GENERAL nouns as regards hemispheric lateralisation, but no conclusive results could be seen. Behaviourally, however, the two noun categories were both predominately judged as concrete in an abstract/concrete categorisation task (compared to ABSTRACT and EMOTIONAL words), although a small but significant difference was present in that GENERAL nouns were categorised as abstract more often than SPECIFIC nouns. In line with the lower imageability values and longer response times for GENERAL nouns, this indicates that GENERAL nouns can be seen as being at a level of abstractness intermediate to that of SPECIFIC and ABSTRACT nouns.

1.2.2 N700

The N400 differences for concrete and abstract words have been obtained using a broad range of tasks, varying in the depth of processing required, but usually thought to necessitate at least lexical access. Among these are tasks such as lexical decision (Barber et al., 2013; Kounios & Holcomb, 1994; Tsai, Yu, Lee, Tzeng, & Hung, 2009) and various semantic tasks including concrete/abstract judgments (Kounios & Holcomb, 1994; West & Holcomb, 2000), semantic relatedness judgments (Tsai et al., 2009), word associations (Welcome, Paivio, McRae, & Joanisse, 2011), mental imagery judgments (Gullick et al., 2013) and imageability ratings (Nittono et al., 2002). The N400 was also reported for a shallow letter search task by Gullick et al. (2013) but not by West & Holcomb (2000).

However, increased negativity for concrete words has also been found in a late time-window extending several hundred milliseconds beyond the N400. This typically anteriorly distributed effect is often labeled 'N700' (Barber et al., 2013; Gullick et al., 2013; Kounios & Holcomb, 1994; Nittono et al., 2002; Welcome et al., 2011; West & Holcomb, 2000). The N700 has been found to be sensitive to depth of processing, and has been linked to sustained processing of imagery information in tasks requiring explicit visual imagery (Gullick et al., 2013; Nittono et al., 2002; West & Holcomb, 2000). It has, however, also been found using a lexical decision task (Barber et al., 2013). The N700 has, however, been studied less extensively than the N400 and the cognitive processes behind it are less well understood. It has been interpreted as reflecting sustained processing of imagery information, which is manipulated in working memory in order to select a response. One region suggested to be involved in this process is the left inferior frontal cortex (West & Holcomb, 2000), but the status of the N700 as a separate component has also been questioned (Nittono et al., 2002).

1.2.3 Abstract and emotional meaning

An EMOTIONAL and an ABSTRACT word category were also distinguished in the current study. The rationale behind this was that emotional content is likely to affect processing of abstract words in particular, with many abstract words being associated with emotional valence to higher degrees than concrete words (Kousta, Vigliocco, Vinson, Andrews, & Del Campo, 2011; Westbury et al., 2013). Emotional words (e.g. *love* or *terror*) are known to be processed differently than neutral words, giving rise to, for example, differences in response-times and memory performance. Emotional word processing has been linked to networks including the medial prefrontal cortex, anterior cingulate cortex and the insula as well as subcortical regions, e.g. the amygdala (Citron, 2012). Comparing the same SPECIFIC, GENERAL, EMOTIONAL and ABSTRACT categories as in the present study, Blomberg et al. (2015) found relatively fast response times for emotional words presented to the left ear, possibly indicating right hemisphere involvement.

Of relevance for the present study, a late centroparietal positivity overlapping with the time-window of the N700, referred to as the late positive complex (LPC) is often found for emotional words (Citron, 2012; Palazova, 2012; Palazova, Mantwill, Sommer, & Schacht, 2011). Despite the difference in scalp distribution, the N700 and LPC might not be entirely straightforward to disentangle. Although not often discussed in the same literature, Kanske & Kotz (2007) use N700/LPC interchangeably to refer to an effect in the 590-750 ms time-window. In a manner similar to the N700, the LPC is most reliably found in tasks when the emotional content of words is task-relevant and where sustained processing of emotion is required, but it has also been found using other semantic tasks as well as in lexical decision tasks (Citron, 2012).

Emotional valence/arousal has been handled in different ways in previous investigations. Most frequently, ERP studies comparing abstract and concrete word processing have not systematically varied or attempted to control for emotional content (Gullick et al., 2013; Kounios & Holcomb, 1992; 1994; Nittono et al., 2002; Welcome et al., 2011; West & Holcomb, 2000). Among the few exceptions are Barber et al. (2013) and Kanske & Kotz (2007). Kanske & Kotz (2007) varied concreteness and emotional valence orthogonally, resulting in comparisons of concrete and abstract words with either positive, neutral or negative valence. They found an interaction of concreteness and emotion, with LPC amplitudes being larger for negatively valenced concrete words. Barber et al. (2013) took emotionality into account by matching their abstract and concrete stimuli along the dimension of emotional valence. They found a behavioural "abstractness effect", i.e. shorter RT's for abstract words, combined with the expected negativity for concrete words in N400 and N700 time-windows.

1.3 The present study

1.3.1 Overall aims

The present study aimed to investigate electrophysiological effects associated with a more diverse spectrum of noun categories than those studied in previous investigations on concrete and abstract words. The goal was to shed more light on semantic processing assumed to be reflected in effects in the N400 and N700 time-windows. Four noun categories varying in imageability (SPECIFIC, GENERAL, EMOTIONAL and ABSTRACT) were compared with phonotactically legal PSEUDOWORDS. The SPECIFIC-GENERAL distinction was of particular interest since it corresponds to the assumed difference in the hierarchical semantic representation of concrete noun concepts in models of lexical semantics (e.g. Miller & Fellbaum, (1991). Although imagery information has been suggested to be more related to SPECIFIC than GENERAL categories, the relation of specificity and imageability is not well understood. Emotional arousal was low for both SPECIFIC and GENERAL categories, intermediate for ABSTRACT nouns and high for EMOTIONAL nouns.

Two different tasks were used: lexical decisions (LD) and imageability ratings (IR). LD was assumed to reflect relatively early stages of lexical processing and to be performed without necessarily activating mental imagery or emotional experiences. The LD task was thus expected to capture effects present during more automatic word processing and was carried out prior to the IR task. IR, on the other hand, was assumed to require explicit activation of mental imagery, and is the type of task which has previously reliably yielded N700 effects. The choice of IR rather than other imagery-related tasks was further motivated by the scarcity of studies investigating the neurophysiological correlates of the IR process, despite the prevalence of IR as an operationalisation of concreteness.

1.3.2 Predicions for concrete nouns, abstract nouns and pseudowords

In line with results from previous studies, PSEUDOWORDS were expected to yield more negative N400 amplitudes than all of the real word categories. Also following results of earlier investigations, more negative N400 and N700 amplitudes were expected for concrete than for abstract words, with high amplitudes in both time-windows predicted for the concrete subcategories SPECIFIC and GENERAL nouns.

Following the same line of reasoning, the processing of the abstract subcategories EMOTIONAL and ABSTRACT nouns was expected to give rise to low N400 and N700 amplitudes in both tasks. Both LD and IR tasks were expected to elicit N400 and N700 effects.

In line with theoretical accounts suggesting that abstract words are primarily organised according to associative relations with other concepts, whereas concrete words are organised based on taxonomic similarity (Crutch et al., 2009), modulations of N400 amplitude were expected to arise due to the testword categories' differences in the degree of association with other words in the mental lexicon. PSEUDOWORDS would not be expected to be associated with any other words semantically, SPECIFIC words with few other words, and abstract words with many other words.

Since the LD task was carried out prior to the IR task, an overall attenuation of N400 amplitudes was expected in the IR task due to repetition.

1.3.3 Predictions for specific-general nouns

The concrete subcategories SPECIFIC and GENERAL nouns were also expected to differ in their neurophysiological patterns. Following their different functions in discourse (Ariel, 1990) as well as their lexical semantic structure (Miller & Fellbaum, 1991), where a GENERAL noun like *animal* may be associated to hyponyms expressing many different subcategories of animals, whereas SPECIFIC nouns like *elephant* could be expected to have fewer lexical assocations and more sensory properties, SPECIFIC nouns were hypothesised to yield larger N400 and possibly also larger N700 amplitudes than GENERAL nouns.

The SPECIFIC stimulus set used in the present study had higher mean imageability than the GENERAL stimulus set. Thus, if the N400 reflects the results of preactivation of semantic features, greater N400 amplitude for SPECIFIC words could be interpreted as a reflection of their greater degree of imageability/concreteness. However, as noted above, large N400 effects have been found for pseudowords, a finding which makes the imageability (sensory feature-related) hypothesis somewhat problematic. Results from two previous ERP studies also indicated that the larger N400 for concrete as compared to abstract words remains even if concrete and abstract word stimulus sets are matched for imageability (Barber et al., 2013), and a larger N400 has also been seen for specific than general words in a study where the general words had higher concreteness (Kounios & Holcomb, 1992). This would indicate another mechanism behind the effect, very possibly related to taxonomic lexical semantic relationships (e.g. hyponymy) between concrete noun categories. In order to see if there would be greater negativity for SPECIFIC words independently of imageability values, a subset of the current study's SPECIFIC – GENERAL stimuli were also matched for imageability (see Appendix 3). If there were larger N400 effects for SPECIFIC than GENERAL words even in the imageability-matched subset, this would further support the hypothesis that N400 effects depend on lexical associations.

1.3.4 Predictions for emotional-abstract nouns

The EMOTIONAL and ABSTRACT categories both had higher emotional arousal than the SPECIFIC and GENERAL categories, but in addition, the EMOTIONAL nouns had significantly higher arousal than the ABSTRACT nouns, which could shed some light on possible effects of emotional arousal on the ERP's. There would then be two possible hypotheses: Either the higher imageability of the EMOTIONAL nouns relative to the ABSTRACT nouns could be expected to result in a concreteness effect, or their higher emotional arousal would be a main factor driving the results. Given the results of previous electrophysiological studies investigating emotional words (Citron, 2012), a posterior positivity for emotional relative to abstract words might be expected, rather than the central/anterior negativity (N700) which has been seen in studies comparing concrete and abstract words.

1.3.5 Predictions for behavioural results

Imageability values were expected to vary from high to low in the order SPECIFIC – GENERAL – EMOTIONAL – ABSTRACT, and response times (RT) were hypothesised to increase from short to long along the same dimension, reflecting the relative ease of accessing imagery information. A similar distribution of RTs was also expected in the LD task, with the shortest RT for SPECIFIC and the longest for ABSTRACT words, based on previously found concreteness effects.

2. Method

2.1 Participants

35 participants (17 female) in the age range of 20-37 years, recruited through Lund University and via social media, took part in the present study. Most of them were university students. All participants were right-handed as assessed by the modified Edinburgh handedness questionnaire (Oldfield, 1971). They all reported normal or corrected-to-normal vision and no history of neurological or psychiatric disease. All participants gave their informed consent to partake in the investigation prior to the experiment. The study was conducted in accordance with the Helsinki Declaration (2000). Participants received an hourly salary.

2.2. Stimuli

Following previous studies targeting the N700 (Barber et al., 2013; Gullick et al., 2013; Welcome et al., 2011; West & Holcomb, 2000), the stimulus words were visually presented. The stimuli consisted of 160 words (see Appendix 1) and 160 pseudowords (see Appendix 2). There were 40 words in each category (SPECIFIC, GENERAL, EMOTIONAL, ABSTRACT). The SPECIFIC words were selected from semantically subordinate levels in relation to the corresponding GENERAL words, i.e. *ekorre* 'squirrel' is on a lexical semantic subordinate level in relation to *djur* 'animal'. The words were all nouns with 1-4 syllables. The stimuli belonging to the different categories were matched for number of syllables and written frequencies from the Stockholm Umeå Corpus (Källgren, Wennstedt & Åström 1992). One-way ANOVAs revealed no significant differences between the word categories as regards number of syllables ($F(3, 156) = 0.113$, $p = 0.952$) or written frequency ($F(3, 156) = 0.007$, $p = 0.999$)). Pseudowords were phonotactically legal and had the same number of syllables as the real words. Kounios & Holcomb (1994) as well as Barber et al. (2013) used pseudowords created from the real concrete and abstract words used in the same experiment, e.g. *teble* and *jastice* (Kounios & Holcomb, 1994). In order to avoid possible associations to real words, such a matching was not used in the present study (see also (Kanske & Kotz, 2007).

When available, imageability ratings for English translations of the words were obtained from the MRC psycholinguistic database (Coltheart, 1981). For items where imageability ratings were not present in the MRC database, Swedish imageability ratings were taken from two data collections carried out prior to the present study (Blomberg & Öberg, 2015; Blomberg, 2016). In order to control for possible between-language differences in word ratings, Swedish ratings of imageability were then used for the same proportion of words in each word category (9/40). A one-way ANOVA showed an effect of word category on imageability ($F(3, 156) = 96.532$, $p < 0.001$) and follow-up Tukey tests revealed significant differences in imageability for each word category (p values < 0.05), going from high-low in the direction SPECIFIC > GENERAL > EMOTIONAL > ABSTRACT.

Emotional arousal ratings were taken from three previous Swedish data collections (Blomberg et al., 2015; Blomberg & Öberg, 2015) Blomberg, 2016. A one-way ANOVA indicated significant differences in emotional arousal between word categories ($F(3, 155) = 157.921$, $p < 0.001$). Post hoc Tukey tests revealed significant differences in emotional arousal between all categories (p values < 0.001), except for GENERAL and SPECIFIC words (p = 0.805). The emotional arousal of test words in the EMOTIONAL category was the highest, followed by those in the abstract category. GENERAL and SPECIFIC words were close to equally low in emotional arousal.

A subset of the GENERAL and SPECIFIC words (see Appendix 3) was selected in order to see whether there would be differences in ERP amplitudes for these different levels of lexical specificity, independently of imageability. The word categories within the subset did not differ significantly in imageability[2] ($F(1, 26) = 0.258$, $p = 0.616$)

2 There was even a non-significant difference in the opposite direction with the general stimuli being slightly higher in imageablity.

emotional arousal ($F(1, 26) = 0.318$, $p = 0.577$), written frequency ($F(1, 26) = 0.049$, $p = 0.826$), or number of syllables ($F(1, 26) = 1.051$, $p = 0.315$).

2.3 Procedure: Lexical Decisions (LD)

The LD experiment was presented using E-Prime 2.0.10 (2012). Participants were seated in front of a Dell EI72FP 17′ computer screen at a distance of 100-110 cm. Written instructions (see Appendix 4a) were presented on the screen prior to the experiment, followed by 24 practice trials with words/pseudowords not appearing in the real experiment. There was an opportunity to ask questions after the practice trials. Words were presented in a white 32p Arial font on a black background. Each trial began with a fixation cross displayed for 500 ms, followed by a word/pseudoword displayed for 1500 ms (Fig. 1). Subjects were instructed to respond as quickly as possible but at the same time to be as careful as possible in making their response. No response feedback was given. Following the 1500 ms word presentation, the next trial began regardless of whether a response was given or not. "Yes/No" responses were given to the question "Is it a real word?" with the left and right index fingers using a PST Serial Response Box. In order to avoid effects of hand dominance, the use of right or left index finger for Yes/No was counterbalanced across participants. All participants carried out the LD task prior to the IR task, since introducing an explicit imagery task beforehand would be likely to introduce unwanted imagery effects into the relatively automatic processing the LD task was intended to capture.

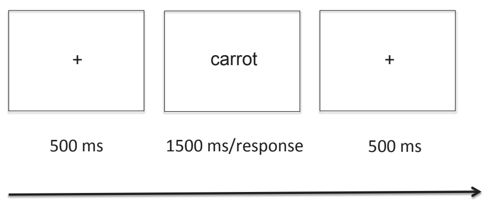


Figure 1
Time course of LD trial.

2.4 Procedure: Imageability Ratings (IR)

Following the LD task, the IR experiment was carried out, also using E-Prime 2.0.10 (2012). Participants were seated in front of a Dell EI72FP 17′ computer screen at a distance of 100-110 cm. Written instructions (see Appendix 4b) were presented on the screen prior to the experiment, followed by 12 practice trials with words/pseudowords not appearing in the experiment. There was an opportunity to ask questions after the practice trials. Words were presented in a white 32p Arial font on a black background. Each trial began with a fixation cross displayed for 500 ms, followed by a stimulus word, which remained on the screen until 1000 ms after a response was made, in order to avoid effects associated with stimulus disappearance (Fig. 2). The imageability ratings were made using the five buttons on a PST Serial Response Box, ranging from 1 = "very difficult to evoke a mental image" to 5 = "very easy to evoke a mental image". Responses were made with the right hand with one finger on each button. In order to avoid response time differences based on finger speed, the order of the rating scale 1(thumb)-5(little finger) or 5(thumb)-1(little finger) was counterbalanced across participants.

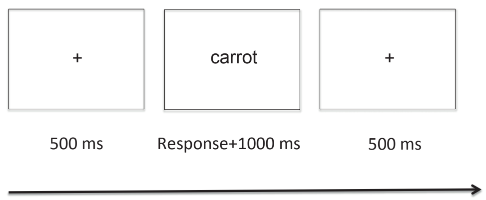


Figure 2
Time course of IR trial.

2.5 Questionnaires

Questionnaires regarding demographic information (e.g. age, sex, regional dialect) and the handedness questionnaire (Oldfield, 1971) were administered prior to the tests. A slightly revised and translated-to-Swedish version of the Vividness of Visual Imagery Questionnaire (VVIQ) (Marks, 1973) as well as a debriefing questionnaire with questions about the LD and IR tasks were completed after the tests.

2.6 EEG recordings

EEG was recorded with 32 electrodes mounted on an elastic cap (Easycap), using a Synamps[2] amplifier and Curry7 software. Electrodes placed at the outer canthi of the eyes and above and below the left eye recorded the electrooculogram. M1 was used as the online reference, re-referenced offline to the average of the mastoids. A frontal cap mounted electrode was used as ground. The scalp electrodes were positioned according to the 10/20 system (Jasper, 1958) as shown in Fig. 3. The sampling rate was 500 Hz and an online bandpass filter (Butterworth) was applied. Electrode impedances were kept below 50 Ohm.

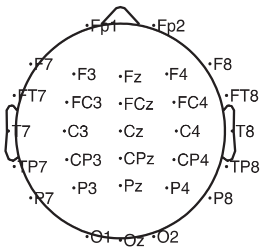


Figure 3
Positioning of the scalp electrodes.

2.7 Data analysis

All statistical analysis of behavioural results was made by means of repeated-measures ANOVAs using SPSS. The EEG data were analyzed offline using EEGLAB (Delorme & Makeig, 2004). An offline bandpass filter with the cutoff frequencies 30 Hz lowpass and 0.05 Hz highpass was applied. The data were then segmented into 1000 ms epochs following word onset. A time window of 200 ms before word onset was used for baseline correction. Independent components analysis (ICA) (Jung, Makeig, Humphries, & Lee, 2000) was used to compensate for ocular artifacts. Trials with an amplitude exceeding ±100 µV after ICA were rejected. One participant was excluded from the analysis of the LD task due to excessively noisy data (>40% rejected). Statistical analysis was performed using SPSS. Mean amplitudes per participant and condition were compared using repeated-measures ANOVAs. For the LD results, five levels of word category (PSEU = PSEUDOWORD / SPEC = SPECIFIC / GEN = GENERAL / EMO = EMOTIONAL / ABS = ABSTRACT) and six ROI:s (LA = LEFT ANTERIOR / MA =

MID ANTERIOR / RA = RIGHT ANTERIOR / LP = LEFT POSTERIOR / MP = MID POSTERIOR / RP = RIGHT POSTERIOR) were included. Analysis of results from the IR task included four levels of word category (only the real word categories) and the same six ROI:s. Pairwise posthoc comparisons were Bonferroni-corrected. Furthermore, in order to be able to see whether possible differences between SPEC and GEN words were driven only by imageability, a subset of the SPEC and GEN stimuli matched for imageability (14 of each category) were analysed. In the cases when Mauchly's test showed violations of the assumption of sphericity, Greenhouse-Geisser correction was applied. In such cases, corrected p-values and uncorrected degrees of freedom are reported.

3. Results

3.1 Behavioural results: Lexical Decision (LD)

Accuracy was high in the LD task (98.1% correct responses) and was the highest for SPECIFIC and EMOTIONAL nouns. RTs varied between word categories (Fig. 4). A repeated-measures ANOVA showed that RTs (ms) were substantially longer for pseudowords (M = 705, SD = 82) as compared to words (M = 629, SD = 62, $F(1, 33) = 49.071$, $p < 0.001$, $\eta^2_p = 0.598$. RT's were fastest for the word categories with the highest imageability (SPEC) (M = 619, SD = 64) and the highest emotional arousal (EMOTIONAL) (M = 625, SD = 63). RT's were longer for GENERAL (M = 635, SD = 63) and ABSTRACT (M = 638, SD = 68) nouns. A repeated-measures ANOVA revealed a significant main effect of word category, ($F(3, 99) = 6.787$, $p < 0.001$, $\eta^2_p = 0.171$. Bonferroni corrected follow-up tests revealed that this effect was due to significant differences between SPECIFIC and GENERAL NOUNS ($p = 0.012$), SPECIFIC and ABSTRACT nouns ($p = 0.001$), and ABSTRACT and EMOTIONAL nouns ($p = 0.021$).

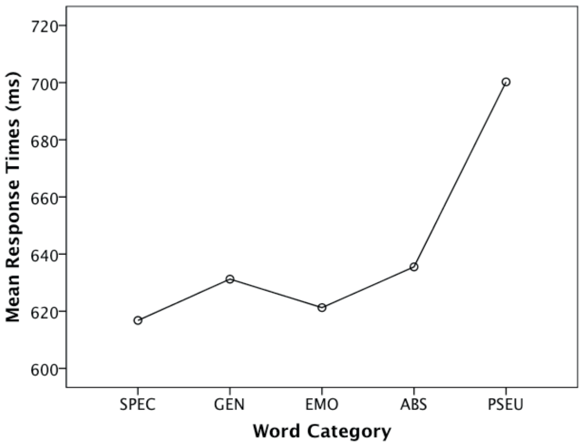


Figure 4
Mean response times for the four word categories (SPEC, GEN, ABS, EMO) and pseudowords (PSEU) in the LD task.

3.2 ERP results: Lexical Decision (LD)

3.2.1 N400 (300-500 ms time-window)

Results from the LD task were consistent with the overall hypothesis that N400 amplitudes would be the largest for PSEUDOWORDS, smaller for concrete (SPECIFIC and GENERAL) nouns and the smallest for abstract (EMOTIONAL and ABSTRACT) nouns (Fig. 5, upper half). A repeated-measures ANOVA revealed a significant main effect of word category ($F(4, 132) =50.636$, $p < 0.001$, $\eta^2_p = 0.605$) as well as a word category x ROI interaction ($F(20, 660) = 3.710$, $p = 0.001$, $\eta^2_p = 0.101$). Bonferroni-corrected post-hoc tests showed that PSEUDOWORDS differed significantly from all other word categories ($p < 0.01$). SPECIFIC nouns also differed significantly from all other categories ($p < 0.01$). GENERAL nouns differed significantly from all categories ($p < 0.01$) except ABSTRACT nouns (p < 0.095). Finally, EMOTIONAL nouns differed significantly from all categories except ABSTRACT nouns where there was trend towards a difference ($p = 0.061$)

3.2.2 N700 (500-800 ms time-window)

Differences in ERPs following word concreteness were also expected in the N700 time-window. A repeated-measures ANOVA showed a significant main effect of wordtype ($F(4, 132) = 3.573$, $p = 0.016$, $\eta^2_p = 0.098$) with no word category x ROI interaction ($F(20, 660) = 0.662$, $p = 0.694$, $\eta^2_p =0.020$). Post hoc tests with Bonferroni correction revealed a significant difference between the SPECIFIC and the

EMOTIONAL category (p = 0.012) and a marginally significant difference between SPECIFIC and ABSTRACT categories (p = 0.058) (Fig. 5, lower half).

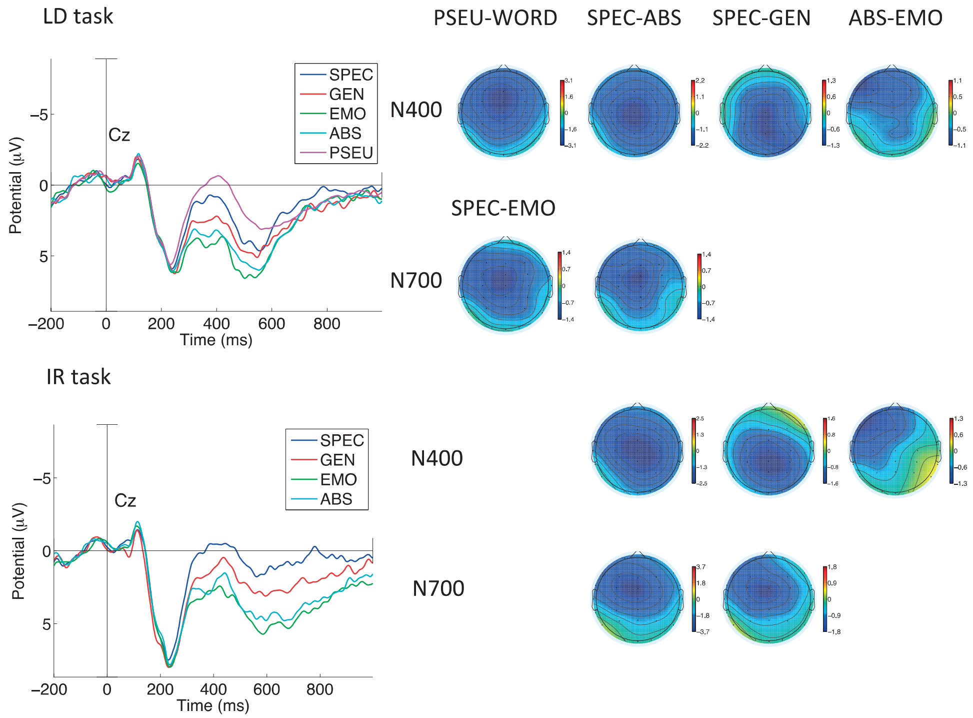


Figure 5
Grand average ERP waveforms for LD and IR tasks, including all wordtypes (SPEC, GEN, EMO, ABS, PSEU), together with topoplots showing the scalp distribution of the most relevant comparisons.

3.3 Behavioural results: Imageability rating (IR) task

In the IR task, the imageability ratings on a 1-5 point scale decreased in the direction SPECIFIC (M = 4.66, SD = 0.482) > GENERAL (M = 3.86, SD = 0.733) > EMOTIONAL (M = 3.09, SD = 0.887) > ABSTRACT (M = 2.37, SD = 0.808) (Fig. 6). A repeated-measures ANOVA showed a significant main effect of word category (F(3, 102) = 108.811, p < 0.001, η^2_p = 0.762). Post hoc comparisons with Bonferroni corrected tests showed that there were significant differences between all four word categories (all p:s < 0.001). RT's corresponded inversely to the IR values, i.e. the higher the IR, the faster the RT (Fig. 7): SPECIFIC (M = 1238, SD = 302) > GENERAL (M = 1503, SD = 494) > EMOTIONAL (M = 1711, SD = 568) > ABSTRACT (M = 1750, SD = 544). A repeated-measures ANOVA revealed a significant main effect of wordtype (F(3, 102) = 37.746, p = 0.001, η^2_p = 0.526). Bonferroni corrected follow-up tests showed that there were significant RT differences between all wordtypes (p values < 0.001), except for ABSTRACT and EMOTIONAL (p = 1.0).

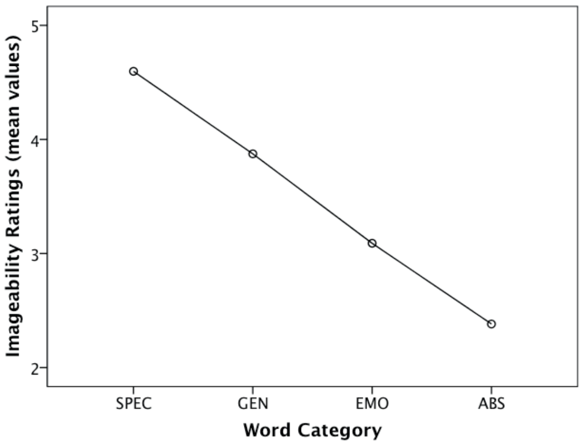


Figure 6
Mean imageability rating values for the four word categories (SPEC, GEN, EMO, ABS) obtained in the IR task.

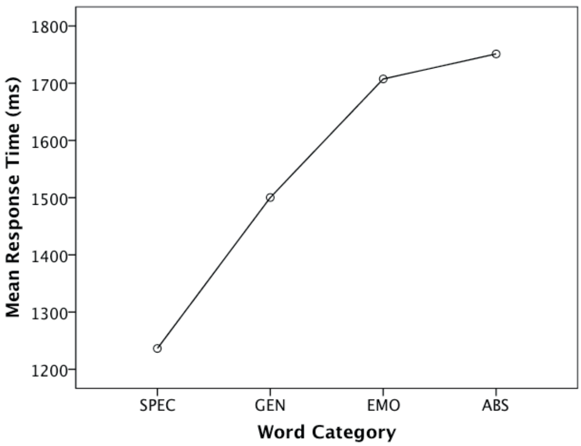


Figure 7
Mean RT's for the four word categories (SPEC, GEN, EMO, ABS) obtained in the IR task.

3.4 ERP results: Imageability rating (IR) task

3.4.1 N400 (300-500 ms time-window)

As expected, similarly to the results seen in the LD task, N400 amplitudes were also larger for word categories higher in imageability. Effects are shown in Fig. 5 (upper half). A repeated-measures ANOVA yielded a significant main effect of word category ($F(3, 102) = 29.778$, $p < 0.001$, $\eta^2_p = 0.467$). There was also an interaction of word category and ROI ($F(15, 510) = 7.023$, $p < 0.001$, $\eta^2_p = 0.171$). Separate rm-ANOVAs were carried out for each ROI, showing significant main effects of word category for all ROIs. Bonferroni-corrected pair-wise comparisons showed significant ($p < 0.05$) differences as follows: LA: all wordtypes, MA: all except EMO/ABS. RA: all except SPEC/GEN and EMO/ABS, LP: all except GEN/ABS and EMO/ABS, MP: all except GEN/ABS and EMO/ABS, RP: all except EMO/ABS. In other words, N400 effects were similar to the effects seen in the LD task, with EMOTIONAL compared to ABSTRACT words only differing over LA electrodes.

3.4.2 N700 (500-800 ms time-window)

The late time-window of the IR task was where the most prominent N700 effects would be expected, given the results of previous studies. Waveforms and topoplots are shown in Fig. 5 (lower half). A repeated-measures ANOVA showed significant main effects of word category ($F(3, 102) = 43.004$, $p < 0.001$, $\eta^2_p = 0.558$) and a word category x ROI interaction ($F(15, 510) = 12.148$, $p < 0.001$, $\eta^2_p = 0.263$). Separate rm-ANOVAS for each ROI with Bonferroni-corrected pair-wise comparisons showed that all comparisons differed significantly over all ROI's, except for SPEC-GEN, EMO-ABS and GEN-ABS. The SPEC-GEN difference was significant only over anterior ROI:s. The EMO-ABS difference was not significant in any ROI. The GEN-ABS comparison was not significant over the LP ROI.

3.5 ERP's for imageability-matched SPECIFIC/GENERAL words

Following visual inspection of the ERP curves from the LD task (Fig. 8, upper part), the subset of SPECIFIC and GENERAL stimuli matched for imageability was compared during a smaller time-window within the N400 range (375-425 ms). Amplitudes were more significantly more negative for SPECIFIC than GENERAL nouns, as shown by a repeated-measures ANOVA ($F(1, 33) = 5.236$, $p = 0.029$, $\eta^2_p = 0.137$), with no significant word category x ROI interaction ($F(5, 165) = 0.576$, $p = 0.719$, $\eta^2_p = 0.017$). In contrast, within the N700 time-window, a repeated-measures ANOVA showed no significant effects for either word category ($F(1, 33) = 0.664$, $p = 0.421$, $\eta^2_p = 0.020$) or word category x ROI ($F(5, 165) = 0.476$, $p = 0.794$, $\eta^2_p = 0.014$).

In the N400 time-window of the IR task, no difference could be seen between the imageability-matched SPECIFIC and GENERAL nouns (Fig. 8, lower part). A repeated-measures ANOVA showed no significant effect of word category ($F(1, 34) = 2.932$, $p = 0.096$, $\eta^2_p = 0.079$) and no significant word category x ROI interaction ($F(5, 170) = 1.139$, $p = 0.342$, $\eta^2_p = 0.032$. However, in the later (500-750) ms time-window, ERP's for SPECIFIC words were significantly more negative than for GENERAL words ($F(1, 34) = 4.189$, $p = 0.048$, $\eta^2_p = 0.110$). There was also a significant word category x ROI interaction ($F(5, 170) = 7.338$, $p < 0.001$, $\eta^2_p = 0.021$). Separate repeated-measures ANOVAS for each ROI with Bonferroni-corrected pair-wise comparisons revealed that SPECIFIC and GENERAL words differed significantly at LA ($p = 0.031$) and MA ($p = 0.026$) electrodes.

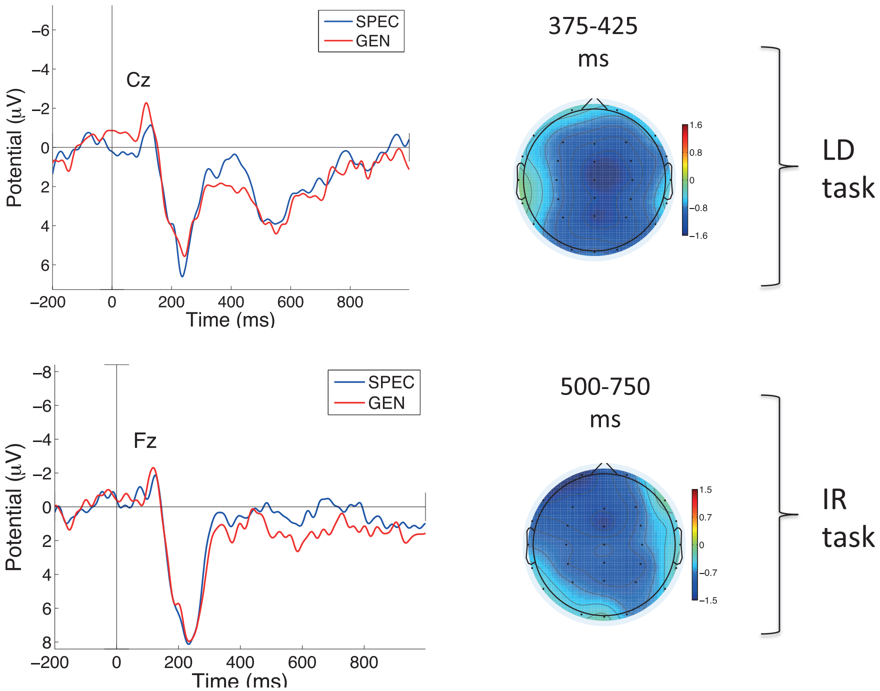


Figure 8
Grand average ERP waveforms for SPEC and GEN words matched for imageability in the LD and IR tasks, together with topoplots showing the scalp distribution of the significant effects.

4. Discussion

4.1 N400 and N700 effects

4.1.1 Accounting for pseudoword, concrete word and abstract word differences

In line with previous studies, larger N400s for pseudowords than real words, as well as larger N400s for concrete than abstract words were found. N400 amplitudes were the most negative for PSEUDOWORDS, followed by the concrete subcategories SPECIFIC and GENERAL nouns, and with the smallest N400s for the abstract subcategories ABSTRACT and EMOTIONAL nouns (see Fig. 5). This variation in N400 amplitudes highlights the fact that neither one of the main accounts proposed to explain the N400, known as the lexical view and the integration view, respectively (Kutas & Federmeier, 2000; Lau et al., 2008), can account for this combination of effects. According to the lexical view, the N400 reflects activation of larger numbers of semantic features in long-term memory. This would explain the larger N400 amplitudes for concrete than for abstract words, but cannot account for the large N400 amplitudes elicited by pseudowords. The integration view, on the other hand, could account for the larger amplitudes for pseudowords, given that they should be less predictable in any context, including isolated word lists, since test-persons have no previous experience with them. However, if predictability is a mechanism driving the results, this does not readily explain why in a comparison of frequency-matched abstract and concrete words presented in isolation, the abstract words would be more predictable.

We would therefore like to propose the alternative hypothesis that the N400 effect might be driven by differences in the degree to which the different word categories are associated semantically with other words in the mental lexicon (from few to many associated lexical items in the direction pseudoword → concrete → abstract). If, as suggested by for instance Crutch et al. (Crutch et al., 2009; 2005), abstract words are conceptually organised in frameworks mainly consisting of associations to other words, whereas concrete words are organised based on taxonomic similarity, this would imply that increasing abstractness leads to an increasing number of word associates. This is also in line with models suggesting that contextual constraints, rather then context availability, may be important for abstract concepts (Wiemer-Hastings et al., 2001). Given that there are such systematic differences in number of lexical associates, this pattern may or may not be related to the degree of imagery information associated with words. The lexical view of the N400 as well Paivio's dual coding theory suggest that concrete words are more associated with processing of sensory features, and the suggestion of similarity-based cognitive frameworks for concrete words (Crutch et al., 2009) would also be compatible with greater degrees of sensory information for concrete words since taxonomic noun categories are related through shared numbers of sensory-related semantic features.

The fact that similar effects were found in both the LD and the IR task, including effects in the 500-800 ms time-window, suggests that an imagery-demanding task is not necessary to elicit the N700, as suggested in previous studies (Gullick et al., 2013; West & Holcomb, 2000). This result is also consistent with those found using LD tasks by Kounios & Holcomb (1994) and Barber et al. (2013). The demands of the two tasks clearly differed, with the LD task being relatively automatic and only requiring "Yes/No" responses, whereas the IR task involved explicit mental imagery and decisions on a 1-5 point scale. Despite this, the effects were in many ways similar in the two tasks, except for the SPECIFIC/GENERAL effect lasting throughout the 500-800 ms time-window of the IR task only. The relative similarities of effects across tasks can be interpreted as supporting the view put forth by Nittono et al. (2002) that the N700 is not necessarily a separate, imagery-demanding component, but may rather be an extension of the N400 reflecting sustained processing of semantic information in working memory.

It should, however, be noted that significant differences in N700 amplitude were found only for SPECIFIC compared to ABSTRACT and EMOTIONAL nouns in the LD task, a result very similar to those previously found comparing concrete and abstract words. The stimuli in the SPECIFIC noun category of the present study can be assumed to be most similar to the highly imageable words constituting the concrete stimuli in a number of previous studies (e.g. *table* (Kounios & Holcomb, 1994), *shoes*, *elephant*, *spider*, *violin*, *umbrella* (West & Holcomb, 2000), *doctor*, *diary*, *baseball* (Nittono et al., 2002), *lamb, moon, pond* (Gullick et al., 2013)). In addition, given the tendency for abstract words to be associated with emotional information (Kousta et al., 2011; Westbury et al., 2013), the ABSTRACT and EMOTIONAL word categories in the present study may both be similar to previously used abstract stimulus lists not controlled for emotional arousal (e.g. *justice* (Kounios & Holcomb, 1994), *bravery, aptitude, greed, equality, chaos* (West & Holcomb, 2000), *effect, interest, theory* (Nittono et al., 2002), *skill, truth, wish* (Gullick et al., 2013)).

4.1.2 Specific-general comparison

The further comparison of the concrete subcategories SPECIFIC and GENERAL nouns yielded significantly more negative ERP's for SPECIFIC words in both tasks (widely distributed N400 effects in both the LD and the IR task, and an anterior N700 in the IR task). This could be interpreted as an imageability effect for the SPECIFIC-GENERAL comparison, being evident even though the SPECIFIC-GENERAL distinction was based on more subtle imageability differences than those of the abstract and concrete words compared in previous studies. However, the subset of SPECIFIC and GENERAL stimuli matched for imageability still yielded significantly greater negativities for SPECIFIC nouns in more limited time-windows in the LD task (375-475 ms), as well as in the IR task (500-750 ms). This suggests that something at least partly different from imageability contributes to the effect, possibly related to the hierarchical semantic relationship between SPECIFIC and GENERAL nouns. The fact that the difference in N400 amplitudes differed significantly for GENERAL and SPECIFIC nouns, but not for GENERAL and ABSTRACT nouns, indicates that although GENERAL nouns are often seen as concrete and are frequently rated as highly imageable, they are nevertheless processed more similarly to ABSTRACT words.

Barber et al. (2013), who matched concrete (high concreteness ratings) and abstract (low concreteness ratings) words for imageability and found N400 and N700 effects in a LD task, interpreted this as challenging the view of the concrete/abstract N700 difference as a function of mental imagery. Instead, they suggested that the number of sensory-motor features associated with words lies behind the effect. However, as noted above, this is perhaps not the whole story, since pseudowords exhibit a greater N400 amplitude despite the fact that they are not associated with sensory-motor features. The use of general nouns to refer back to specific nouns in discourse (Ariel, 1990) would be compatible with a pattern where GENERAL nouns have connection to larger numbers of other lexical items. This would also explain the N400 differences seen for a subset of SPECIFIC and GENERAL words matched for imageability in the present study, which would be difficult to explain based on their different degrees of association with sensory semantic features only.

4.1.3 Emotional-abstract comparison

Unlike the other word categories, the EMOTIONAL-ABSTRACT comparison did not follow the pattern of increasingly negative amplitudes for increasingly imageable words. In contrast, EMOTIONAL words, despite having higher imageability, gave rise to more positive amplitudes than ABSTRACT words. The EMOTIONAL-ABSTRACT comparison yielded significant differences in the N400 over left anterior electrodes in the IR task, and a trend towards a difference in the LD task. One could speculate that emotional content influences the ERPs in a way similar to the emotion-related LPC, with more positive-going waves for words with higher emotional arousal (although the distribution in the present study was left anterior rather than posterior). Since the ABSTRACT word category in the present study had emotional arousal values that lay between the SPECIFIC/GENERAL words (low arousal) and the EMOTIONAL words (high arousal), and at the same time had higher imageability, further studies would benefit from matching the emotional arousal values of ABSTRACT stimuli with those of SPECIFIC/GENERAL stimuli, and/or (if possible) matching the imageability values of ABSTRACT and EMOTIONAL words, in order to be able to tease apart the contributions of sensory and emotional information in word processing.

4.2 Behavioural results

In the LD task, RT's were the fastest for SPECIFIC and EMOTIONAL nouns, suggesting that concrete nouns associated with relatively many sensory features (high imageability) as well nouns associated with emotional experiences (high emotional arousal) facilitated lexicality decisions. RT's were substantially longer for PSEUDOWORDS than for real words. For the IR task, the behavioural data showed that the present study's word ratings corresponded well to the four imageability levels of the testword categories (SPECIFIC > GENERAL > EMOTIONAL > ABSTRACT), confirming that the present study's "online" IR were comparable to those previously obtained using an ordinary "offline" IR task. RTs increased in the opposite direction (SPECIFIC < GENERAL < EMOTIONAL < ABSTRACT), as would be expected if the RTs reflected a 'concreteness effect' (Paivio, 2010; Welcome et al., 2011), i.e. faster processing of highly imageable/concrete words. The fact that RTs were not shorter for the EMOTIONAL category in the IR task, as they were in the LD task, may be due to facilitating effects of emotion being relatively early and transient.

4.3 Challenges in experiment design

There are some challenges involved in designing experiments with SPECIFIC and GENERAL noun stimuli. One is that as a consequence of the hierarchical lexical semantic structure, there are naturally fewer possible stimuli on the GENERAL level (e.g. *vegetable*) than on the SPECIFIC level (e.g. *carrot, tomato, cucumber* etc). In the study of (Kounios & Holcomb, 1992), this resulted in a stimulus set where the more general, but not the more specific words were repeated several times. In the present study, equal numbers of SPECIFIC and GENERAL words were used. Nevertheless, since a within-subjects design was used with hierarchically related words, priming effects are likely to occur. The question is then if these priming effects would be systematically different for the SPECIFIC and GENERAL stimuli. It might be the case that the GENERAL stimuli are more likely to be primed by SPECIFIC stimuli, making them more predictable in the context of the experiment. For example, the SPECIFIC words *ekorre* 'squirrel, *skalbagge* 'beetle', and *elefant* 'elephant' can all be included under the GENERAL label *djur* 'animal'. Although the GENERAL words *art* 'species' and *insekt* 'insect' were also included in the experiment in order to balance the stimuli sets, the word *djur* 'animal' might be a more prototypical superordinate category for all of the given exemplars. This could contribute to the more positive N400 amplitudes associated with the GENERAL words. On the other hand, there are also some items within the SPECIFIC category that are likely to prime each other, e.g. *kaffe* 'coffee' and *tårta* 'cake', and the random presentation of words could be expected to diminish effects due to particular stimuli priming each other occurring in a certain order.

Another challenge lies in finding words at suitable levels of specificity for the testword categories. In order to be able to include equally many different SPECIFIC and GENERAL stimuli in the present study, some variation on the GENERAL level could not be avoided. For example, *grej* 'thing' and *verktyg* 'tool' are both classified as GENERAL nouns, although the first is a superordinate category of the other. This classification was, however, made in relation to the SPECIFIC words *boll* 'ball' and *hammare* 'hammer' respectively, whose meanings are more specific as regards e.g. visual appearance and functions than both the GENERAL nouns.

4.4 General discussion

The results of the present study have implications for the interpretation of N400 effects. It was shown that the main theoretical frameworks explaining the N400 effect cannot account for the patterning of the N400 in a comparison of pseudowords, concrete nouns and abstract nouns. An alternative proposal, i.e. that N400 amplitudes are modulated by the number of lexical associates was proposed. In the N400 amplitude distribution (PSEUDOWORD > SPECIFIC > GENERAL > EMOTIONAL > ABSTRACT), differences for each noun category are straightforwardly accounted for by this model, with the exception of EMOTIONAL and ABSTRACT nouns. The greater N400 for EMOTIONAL nouns could, however, be accounted for if it is the case that their high emotional arousal increases the number of lexical associations as compared to the less emotionally arousing ABSTRACT noun category.

4.4.1. Future studies

Given the rather poor spatial resolution of the EEG methodology, the present study cannot provide any detailed information regarding the neural processes that can be assumed to contribute to the differences in N400 effects. The N400 is likely to have several different generators (Lau et al., 2008). In a study by Adorni & Proverbio (2012) the source localisation technique 'Low Resolution Electromagnetic Tomography' (LORETA) (Palmero-Soler & Dolan, 2007) was used, relating EEG activity for words as compared to pseudowords with activity in the left fusiform gyrus and left temporal cortex, whereas the concrete - abstract word contrast was seen to be associated with stronger activation in left extrastriate visual cortex. Using similar localisation techniques, or a method with high spatial as well as temporal resolution, such as magnetoencephalography (MEG), further studies could shed more light on the question as regards which subprocesses and which brain regions contribute to the ERP differences observed in the present study.

Acknowledgements

The present study was supported by grants 421-2004-8918 and 349-2007-8695 from the Swedish Research Council and was carried out at the Humanities Lab at Lund University. We wish to thank Anna Hed for help with data collection.

5. References

Adorni, R., & Proverbio, A. M. (2012). The neural manifestation of the word concreteness effect: An electrical neuroimaging study. *Neuropsychologia 50,* 880-891.

Barber, H. A., Otten, L. J., Kousta, S.-T., & Vigliocco, G. (2013). Concreteness in word processing: ERP and behavioral effects in a lexical decision task. *Brain and Language*, *125*(1), 47–53. http://doi.org/10.1016/j.bandl.2013.01.005

Blomberg, F., & Öberg, C. (2015). Swedish and English word ratings of imageability, familiarity and age of acquisition are highly correlated. *Nordic Journal of Linguistics*, *38*(3), 351–364. http://doi.org/10.1017/S0332586515000220

Blomberg, F., Roll, M., Lindgren, M., Brännström, K. J., & Horne, M. (2015). Emotional arousal and lexical specificity modulate response times differently depending on ear of presentation in a dichotic listening task. *The Mental Lexicon*, *10*(2), 221–246. http://doi.org/10.1075/ml.10.2.03blo

Citron, F. M. M. (2012). Neural correlates of written emotion word processing: A review of recent electrophysiological and hemodynamic neuroimaging studies. *Brain and Language*, *122*(3), 211–226. http://doi.org/10.1016/j.bandl.2011.12.007

Coltheart, M. (1981). The MRC psycholinguistic database. *The Quarterly Journal of Experimental Psychology Section A*, *33*(4), 497–505. http://doi.org/10.1080/14640748108400805

Crutch, S. J. (2006). Qualitatively Different Semantic Representations for Abstract and Concrete Words: Further Evidence from the Semantic Reading Errors of Deep Dyslexic Patients. *Neurocase*, *12*(2), 91–97. http://doi.org/10.1080/13554790500507172

Crutch, S. J., & Warrington, E. K. (2005). Abstract and concrete concepts have structurally different representational frameworks. *Brain*, *128*(3), 615–627. http://doi.org/10.1093/brain/awh349

Crutch, S. J., & Warrington, E. K. (2010). The differential dependence of abstract and concrete words upon associative and similarity-based information: Complementary semantic interference and facilitation effects. *Cognitive Neuropsychology*, *27*(1), 46–71. http://doi.org/10.1080/02643294.2010.491359

Crutch, S. J., Connell, S., & Warrington, E. K. (2009). The different representational frameworks underpinning abstract and concrete knowledge: Evidence from odd-one-out judgements. *The Quarterly Journal of Experimental Psychology*, *62*(7), 1377–1390. http://doi.org/10.1080/17470210802483834

Delorme, A., & Makeig, S. (2004). EEGLAB: an open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. *Journal of Neuroscience Methods 134* (1), 9-21.

Ejerhed E., Källgren G., Wennstedt O. & Åström M. (1992). The linguistic annotation system of the Stockholm-Umeå Corpus project. *Tech Rep 33*, Department of General Linguistics, Umeå University, Umeå, Sweden.

Gilhooly, K. J., & Logie, R. H. (1980). Age-of-acquisition, imagery, concreteness, familiarity, and ambiguity measures for 1,944 words. *Behavior Research Methods*, *12*(4), 395–427. http://doi.org/10.3758/BF03201693

Gullick, M. M., Mitra, P., & Coch, D. (2013). Imagining the truth and the moon: An electrophysiological study of abstract and concrete word processing. *Psychophysiology*, *50*(5), 431–440. http://doi.org/10.1111/psyp.12033

Jasper, H.H. (1958). The ten twenty electrode system of the international federation. *Electroencephalography and Clinical Neurophysiology, 10*, 371-375.

Jung, T. P., Makeig, S., Humphries, C., & Lee, T. W. (2000). Removing electroencephalographic artifacts by blind source separation. *Psychophysiology 37* (2), 163-178.

Kanske, P., & Kotz, S. A. (2007). Concreteness in emotional words: ERP evidence from a hemifield study. *Brain Research*, *1148*, 138–148. http://doi.org/10.1016/j.brainres.2007.02.044

Kounios, J., & Holcomb, P. J. (1992). Structure and process in semantic memory: Evidence from event-related brain potentials and reaction times. *Journal of Experimental Psychology: General*, *121*(4), 459–479. http://doi.org/10.1037/0096-3445.121.4.459

Kounios, J., & Holcomb, P. J. (1994). Concreteness effects in semantic processing: ERP evidence supporting dual-coding theory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *20*(4), 804–823. http://doi.org/10.1037/0278-7393.20.4.804

Kousta, S.-T., Vigliocco, G., Vinson, D. P., Andrews, M., & Del Campo, E. (2011). The representation of abstract words: Why emotion matters. *Journal of Experimental Psychology: General*, *140*(1), 14–34. http://doi.org/10.1037/a0021446

Kutas, M., & Federmeier, K. D. (2000). Electrophysiology reveals semantic memory use in language comprehension. *Trends in Cognitive Sciences 4*(12), 463-470.

Kutas, M., & Federmeier, K. D. (2011). Thirty Years and Counting: Finding Meaning in the N400 Component of the Event-Related Brain Potential (ERP). *Annual Review of Psychology*, *62*(1), 621–647. http://doi.org/10.1146/annurev.psych.093008.131123

Kutas, M., & Hillyard, S. A. (1980). Reading senseless sentences: Brain potentials reflect semantic incongruity. *Science 207* (4427), 203-205.

Lau, E. F., Phillips, C., & Poeppel, D. (2008). A cortical network for semantics: (de)constructing the N400. *Nature Reviews Neuroscience, 9*(12), 920–933. http://doi.org/10.1038/nrn2532

Lyons, J. (1977). *Semantics*, 2 vols. Cambridge: Cambridge University Press.

Marks, D. F. (1973), Visual imagery differences in the recall of pictures. *British Journal of* Psychology, 64, 17–24. doi: 10.1111/j.2044-8295.1973.tb01322.

Miller, G. A., & Fellbaum, C. (1991). Semantic networks of English. *Cognition 41*, 197-229.

Nittono, H., Suehiro, M., & Hori, T. (2002). Word imageability and N400 in an incidental memory paradigm. *International Journal of Psychophysiology 44*, 219-229.

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychologia*, *9*(1), 97–113. http://doi.org/10.1016/0028-3932(71)90067-4

Paivio, A. (1990). *Mental Representations*. Oxford Psychology Series.

Paivio, A. (2010). Dual coding theory and the mental lexicon. *The Mental Lexicon*, *5*(2), 205–230. http://doi.org/10.1075/ml.5.2.04pai

Paivio, A., Yuille, J. C., & Madigan, S. A. (1968). Concreteness, imagery, and meaningfulness values for 925 nouns. *Journal of Experimental Psychology*, *76*(1, Pt.2), 1–25. http://doi.org/10.1037/h0025327

Palazova, M. (2012). *The Functional Locus of Emotion Effects in Visual Word Processing*, 1–35. Doctoral Dissertation. Humboldt Universität Berlin.

Palazova, M., Mantwill, K., Sommer, W., & Schacht, A. (2011). Are effects of emotion in single words non-lexical? Evidence from event-related brain potentials. *Neuropsycholo*gia 49, 2766-2775.

Palmero-Soler, E., Dolan, K., Hadamschek, V., & Tass, P. A. (2007). swLORETA: A novel approach to robust source localization and synchronization tomography. *Physics in Medicine & Biology, 52*, 1783–1800.

Psychology Software Tools, Inc. [E-Prime 2.0]. (2012). Retrieved from http://www.pstnet.com.

Rosch, E., & Lloyd, B. B. (1978). *Cognition and Categorization*. New Jersey: Lawrence Erlbaum

Rosch, E., Mervis, C. B., Gray, W. D., Johnson, D. M., & Boyes-Braem, P. (1976). Basic objects in natural categories. *Cognitive Psychology*, *8*(3), 382–439. http://doi.org/10.1016/0010-0285(76)90013-X

Rugg, M. D. (1985). The Effects of Semantic Priming and Word Repetition on Event-Related Potentials. *Psychophysiology*, *22*(6), 642–647. http://doi.org/10.1111/j.1469-8986.1985.tb01661.x

Sabsevitz, D. S., Medler, D. A., Seidenberg, M., & Binder, J. R. (2005). Modulation of the semantic system by word imageability. *NeuroImage*, *27*(1), 188–200. http://doi.org/10.1016/j.neuroimage.2005.04.012

Schwanenflugel, P. J., & Shoben, E. J. (1983). Differential context effects in the comprehension of abstract and concrete verbal materials. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *9*(1), 82–102. http://doi.org/10.1037/0278-7393.9.1.82

Tsai, P. S., Yu, B., Lee, C. Y., Tzeng, O., & Hung, D. L. (2009). An event-related potential study of the concreteness effect between Chinese nouns and verbs. *Brain Research 1253*, 149-160.

Welcome, S. E., Paivio, A., McRae, K., & Joanisse, M. F. (2011). An electrophysiological study of task demands on concreteness effects: evidence for dual coding theory. *Experimental Brain Research*, *212*(3), 347–358. http://doi.org/10.1007/s00221-011-2734-8

West, W. C., & Holcomb, P. J. (2000). Imaginal, semantic, and surface-level processing of concrete and abstract words: an electrophysiological investigation. *Journal of Cognitive Neuroscience*, *12*(6), 1024–1037.

Westbury, C. F., Shaoul, C., Hollis, G., Smithson, L., Briesemeister, B. B., Hofmann, M. J., & Jacobs, A. M. (2013). Now you see it, now you don't: on emotion, context, and the algorithmic prediction of human imageability judgments, *Frontiers in Psychology* 4(991), 1–13. http://doi.org/10.3389/fpsyg.2013.00991/abstract

Westbury, C., & Moroschan, G. (2009). Imageability x phonology interactions during lexical access: Effects of modality, phonological neighbourhood, and phonological processing efficiency. *The Mental Lexicon*, *4*(1), 115–145. http://doi.org/10.1075/ml.4.1.05wes

Wiemer-Hastings, K., Krug, J., & Xu, X. (2001). Imagery, context availability, contextual constraint, and abstractness. *Proceedings of the 23rd Annual Conference of the cognitive science society* 1134-1139. Mahway: Lawrence Erlbaum Associates.

World Medical Association Declaration of Helsinki. (2000).

Appendix 1: Swedish words belonging to the four semantic categories with English translations

SPECIFIC		GENERAL		EMOTIONAL		ABSTRACT	
ekorre	squirrel	djur	animal	kärlek	love	råd	advice
banan	banana	frukt	fruit	glädje	joy	rykte	rumour
träd	tree	växt	plant	oro	worry	löfte	promise
hammare	hammer	verktyg	tool	sorg	sorrow	moral	morale
paraply	umbrella	pryl	gadget	lycka	luck	plikt	duty
bil	car	fordon	vehicle	mod	courage	datum	date
bord	table	möbel	furniture	lust	lust	stil	style
kvinna	woman	individ	individual	längtan	yearning	svar	answer
pistol	gun	vapen	weapon	humor	humour	prestige	prestige
plast	plastic	material	material	skräck	horror	mognad	maturity
kaffe	coffee	dryck	beverage	tröst	comfort	variation	variety
tårta	cake	bakverk	pastry	skam	shame	magi	magic
potatis	potato	grönsak	vegetable	ilska	anger	visdom	wisdom
hus	house	byggnad	building	sjukdom	disease	idé	idea
peppar	pepper	krydda	spice	lättnad	relief	ordning	order
dator	computer	redskap	tool	chock	shock	position	position
majs	corn	gröda	crop	framgång	success	arv	heritage
skalbagge	beetle	insekt	insect	hat	hatred	fakta	fact
boll	ball	grej	thing	kris	chrisis	term	term
soppa	soup	mat	food	förakt	contempt	rutin	routine
jeans	jeans	plagg	garment	förälskelse	love	bevis	evidence
klocka	clock	instrument	instrument	kaos	chaos	fas	phase
flaska	flask	behållare	container	död	death	tendens	tendency
mjölk	milk	produkt	product	spänning	excitement	behov	need
cykel	bicycle	farkost	vehicle	frihet	freedom	metod	method
telefon	telephone	apparat	device	krig	war	brist	lack
flygplan	airplane	maskin	machine	skada	harm	fakta	fact
elefant	elephant	art	species	njutning	pleasure	mängd	amount
tavla	painting	konst	art	problem	problem	avsikt	intention
torg	market	plats	place	vänskap	friendship	uppehåll	pause
diamant	diamond	smycke	jewelery	svartsjuka	jealousy	tradition	tradition
låda	box	för- packning	package	stress	stress	tanke	thought
tallrik	plate	husgeråd	cookware	besvikelse	disappoint- ment	ritual	ritual
docka	doll	leksak	toy	depression	depression	reaktion	reaction
kärna	kernel	innehåll	content	tacksamhet	gratitude	attityd	attitude
papegoja	parrot	organism	organism	passion	passion	överflöd	abundance

guld	gold	metall	metal	belöning	reward	tema	theme
hjärta	heart	organ	organ	med-lidande	pity	gåta	riddle
hav	sea	miljö	environ-ment	förtjusning	delight	dröm	dream
schack	chess	spel	game	liv	life	stil	style

Appendix 2: Pseudowords

nir	bråll	vorsänta	svand	lömm	seval	darbar	berunnare
drigg	åstroskant	midåg	bruska	geno	sep	märno	veol
kemp	destuckare	knyp	malpa	ölde	chavars	yna	bik
pelkop	trymust	meralde	vuss	topeg	hilem	kerp	grallsick
flom	jumbalk	nebanog	tundel	drup	pådir	tjorra	bramid
låkdik	omarin	jok	liromed	funner	skjunn	pum	dråv
sontes	lotun	hynk	pranbin	frop	bamme	storv	fluna
danalod	kråp	bolke	filadonk	plen	bross	perstan	lumang
guser	svink	lintes	kirpa	frischor	frädbolt	måver	klåtrin
gilerel	spåck	kväng	frim	tålned	ynnalig	spruss	mäklut
fripp	skrybbe	dinto	kolanid	presolitur	nalsiped	plarp	brykdrata
trinfrut	söldurvig	gocka	pala	tevå	fallin	svåll	skrapp
pycklins	vilermål	måsita	dinrom	porden	fiderul	ärste	feglytare
hillmak	piltyn	dor	fånna	öri	dragapar	klymbar	gnittrasvup
blinna	olanark	fixlan	sjulle	haskar	fostaråg	åmman	bretiflat
almsimp	predovås	jopa	gådovinga	halamin	feralev	svack	tropul
driska	eming	soms	ird	olk	gara	grungtag	gekvupel
engrist	palit	pluderka	kambe	nålda	timla	lis	möndavare
kluk	rosir	näms	pät	korm	prug	drem	beklyping
vop	knik	fonna	haln	derut	frås	hurapt	svub

Appendix 3: Imageability-matched SPECIFIC and GENERAL words

SWEDISH	ENGLISH	CATEGORY	IMAG	EMO	FREQ (SUC)	SYLL
hav	sea	SPEC	606	427	91	1
soppa	soup	SPEC	604	170	18	2
tavla	painting	SPEC	602	259	33	2
majs	corn	SPEC	601	191	6	1
guld	gold	SPEC	594	309	38	1
paraply	umbrella	SPEC	592	237	9	3
låda	box	SPEC	591	118	30	2
peppar	pepper	SPEC	587	177	3	2
torg	market	SPEC	583	209	44	1
bord	table	SPEC	582	130	134	1
docka	doll	SPEC	565	214	17	2
kärna	kernel	SPEC	542	218	37	2
tallrik	plate	SPEC	527	132	11	2
plast	plastic	SPEC	505	182	22	1
bakverk	pastry	GEN	609	227	2	2
växt	plant	GEN	605	200	74	1
smycke	jewelery	GEN	605	227	8	2
grönsak	vegetable	GEN	598	180	1	2
fordon	vehicle	GEN	593	173	24	2
farkost	vehicle	GEN	593	173	5	2
krydda	spice	GEN	592	197	8	2
möbel	furniture	GEN	588	150	20	2
frukt	fruit	GEN	587	203	25	1
insekt	insect	GEN	586	245	10	2
djur	animal	GEN	575	300	218	1
dryck	beverage	GEN	565	210	30	1
behållare	container	GEN	532	118	2	4
förpackning	package	GEN	529	127	10	3

Appendix 4a: Instructions for LD experiment

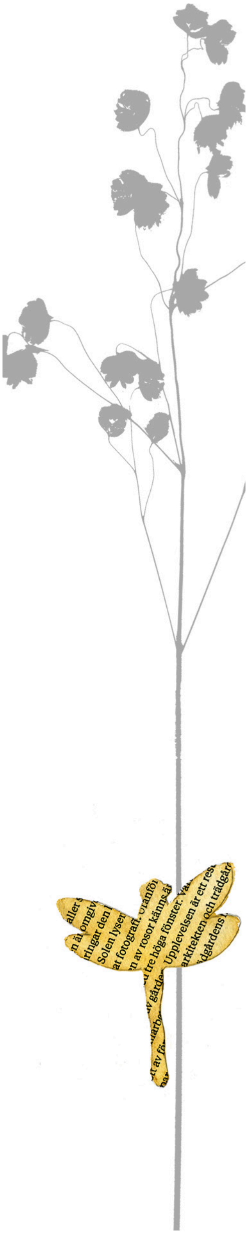
I det här experimentet kommer du att få se omväxlande riktiga ord och låtsasord som dyker upp på skärmen. Din uppgift är att besvara frågan "Är det ett riktigt ord?". Du ska alltså svara "ja" om det är ett riktigt ord och "nej" om det är ett låtsasord, med hjälp av de två knapparna på lådan framför dig. Håll hela tiden dina pekfingrar på knapparna så du är redo att svara. Svara så snabbt du kan, men var samtidigt noggrann. Innan det riktiga experimentet börjar kommer du att få prova med några övningsexempel.	In this experiment real words and pretend words will appear randomly on the screen. Your task is to answer the question "Is it a real word?". In other words, you should answer "yes" if it is a real word and "no" if it is a pretend word, using the two buttons on the box in front of you. Keep your index fingers on the buttons so you are ready to respond. Please respond as quickly as possible, but at the same time, be careful in making your responses. Before the real experiment begins there will be some practice examples.

Appendix 4b: Instructions for IR experiment

Nu kommer du att få bedöma hur lätt det är att föreställa sig så kallade "mentala bilder" kopplade till ett antal ord på en skala 1-5. Du kommer att känna igen orden från ordexperiment 1. Det kommer strax en närmare beskrivning av mentala bilder och av stegen på skalan. Det varierar hur starkt olika ord är associerade med så kallade "mentala bilder". Mentala bilder är inre sinnesupplevelser som kan vara visuella, men de kan också vara ljud-, känsel-, doft- eller smakupplevelser. En del ord väcker snabbt och lätt tydliga mentala bilder till liv, medan andra ord kan göra det med viss ansträngning och vissa ord väcker inte några mentala bilder alls. Din uppgift är att poängsätta ord beroende på hur lätt de väcker mentala bilder. Skalan sträcker sig mellan 1-5, där 1 är svårast att föreställa sig en mental bild för och 5 är lättast att föreställa sig. De ord som snabbt och lätt väcker mentala bilder ska få en hög poäng. De ord som med svårighet eller inte alls väcker mentala bilder ska ges en låg poäng. Du svarar med hjälp av de 5 knapparna på	Your task is now to rate how easy it is to imagine so-called "mental images" related to a number of words on a scale ranging from 1-5. You will recognise the words from word experiment 1. Mental images and the steps of the scale will soon be described in more detail. Words differ in their capacity to arouse so-called "mental images". Mental images are inner sensory experiences which may be visual, but they may also involve experiences of sound, touch, smell or taste. Some words arouse mental images quickly and easily, whereas other words may do so only with difficulty and some words do not arouse any mental images at all. Your task is to rate words as to the ease with which they arouse mental images. The rating scale ranges from 1-5, with 1 being the most difficult to arouse a mental image for and 5 being the easiest to imagine. Any word which arouses a mental image quickly and easily should be given a high rating. Any word that arouses an image with difficulty or not at all should be given a low

boxen framför dig. Ett papper med beskrivning av skalan finns bredvid dig.	rating. You respond using the 5 buttons on the box in front of you. A paper with a description of the scale is beside you.
Gör bedömningarna baserat på ditt första intryck. Känn dig fri att använda hela skalan, men bry dig inte om hur ofta du använder en viss siffra så länge den motsvarar din verkliga bedömning av hur starka mentala bilder/inre sinnesupplevelser ordet väcker. Det finns inga "rätt" eller "fel" svar – syftet är att få reda på hur tydliga mentala bilder ordet väcker för dig. Innan det riktiga experimentet börjar kommer du att få öva några gånger på att bedöma mentala bilder. Tryck på valfri knapp för att börja.	Ratings should be made on the basis of your first impression. Feel free to use the entire range of numbers, but at the same time, do not be concerned about how often you use a particular number as long as it is your true assessment of how strong mental images/inner sensory experiences the word arouses. There are no "right" or "wrong" responses – the purpose is for us to know how vivid mental images the word arouses for you. Before the real experi-ment you will get some practice in assessing mental images. Please press any button to begin.
Kom ihåg att skalan är som följer: 1 (tummen) = mycket svårt att föreställa sig mental bild 2 3 4 5 (lillfingret) = mycket lätt att föreställa sig en mental bild	Remember that the rating scale is as follows: 1 (thumb) = very difficult to arouse a mental image 2 3 4 5 (little finger) = very easy to arouse a mental image

Printed by Media-Tryck, Lund University 2016



Concreteness, Specificity and Emotional Content in Swedish Nouns

Neurocognitive Studies of Word Meaning

In everyday life as well as in research contexts, concrete and abstract nouns are commonly conceived as two distinct categories. Whereas concrete nouns such as *äpple* 'apple' have referents which can be experienced with the five senses, abstract nouns such as *frihet* 'freedom' refer to concepts which cannot be seen, heard, tasted, smelled or touched. The present thesis investigates the semantic representations and processes associated with Swedish concrete and abstract nouns, with a focus on their relation to sensory and emotional content and their degree of semantic specificity. Two concrete noun subcategories (SPECIFIC, e.g. *ekorre* 'squirrel' and GENERAL, e.g. *djur* 'animal') and two abstract noun subcategories (EMOTIONAL, e.g. *glädje* 'joy' and ABSTRACT, e.g. *teori* 'theory') are investigated. An interdisciplinary approach is taken, combining theoretical models and methods from linguistics, cognitive psychology and neuroscience.

The thesis includes four papers investigating noun meanings using different linguistic, psycholinguistic and neurolinguistic methods. Paper I focuses on word meanings in spoken discourse produced by a person with lesions in brain regions involved in visual information processing. This person's word-finding difficulties are shown to be modality-specific, selectively affecting SPECIFIC words rich in visual semantic features. Paper II compares subjective ratings of cognitive psychological parameters for a number of Swedish and English words and briefly outlines a proposal for constructing a Swedish psycholinguistic database. Using a dichotic listening technique, Paper III relates EMOTIONAL nouns to activation in the right hemisphere of the brain. The study reported on in Paper IV uses electroencephalography (EEG) to investigate neurophysiological differences between the four word categories as well as pseudowords (e.g. *kvup*). The results provide important insights into the differences between the word categories assumed in lexical semantic and neurocognitive models of concrete and abstract word meaning.

LUND UNIVERSITY

LUND UNIVERSITY
General Linguistics
Centre for Languages and Literature
Doctoral Dissertation, 2016
ISBN 978-91-87833-75-5