An Image is Worth a Thousand Sounds?

On Imageability and Phonological Neighborhood Density Effects in Speech Processing

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Synopsis

This thesis focuses on one semantic and one phonological factor that have separately been proven to have an influence on lexical access, both in speech perception and production. The factors are imageability, how easily a word gives rise to a mental sensory image, and phonological neighborhood density, how similar sounding words are, respectively.

A main goal of this thesis has been to see if there is an interaction between the two factors in speech production and perception, and if the two factors behave in a similar manner. Two informant groups were tested in a visual and auditory lexical decision task for perception and a picture naming task for production. One group consisted of three male subjects with an acquired, focal language disorder (aphasia), and the other group consisted of 30 neurologically healthy informants. The words they were tested on came from four different word groups: high imageability and high phonological neighborhood density (PND) words, high imageability and low PND words, low imageability and high PND words, and low imageability and low PND words. The informants were tested both on reaction time and accuracy.

To find the right words for testing I had to calculate the phonological neighborhood density for words that already had received imageability scores. This has been a rather large part of the work with this thesis, as there was no information about Norwegian words' phonological neighborhood density before I started this work.

Based on previous research the expected results would be that high imageability words would be recognized and produced faster than the low imageability ones. High PND words should follow the same pattern in production, but would be expected to have longer response latencies than low PND words in perception. The results from this study, however, show that imageability is the only factor that behaves according to the predictions. Phonological neighborhood density does not show any significant effects, nor is there any interaction between the two factors. There is a tendency, however, that high phonological neighborhood density slows down both perception and production of words, which is a quite unexpected finding, based on previous research. This might suggest that a word's imageability is a more important factor for lexical access than the phonological properties of the word. The informants with and without aphasia show similar patterns for the two tasks, which indicates that speech processing is controlled by the same mechanisms for speakers with and without acquired, focal language deficits.

Acknowledgments

This thesis marks the end of an era. When I started my BA in linguistics, the Master's program seemed far away, and at times completely unreachable. As I grew more and more fond of linguistics I knew I had to give it a try. Today I'm really happy I did, and at the same time sad that it is over.

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Oslo, November 2012

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LIST OF ABBREVIATIONS

ACTUATE = Assessing Cases, the University of Alberta Test Environment

AD =Alzheimer's disease

ALD = Auditory Lexical Decision

ANOVA = Analysis of Variance

AVLD = Auditory and Visual Lexical Decision

BA = Broca's Aphasia

DS = Down's syndrome

ERP =Event-related Potentials

fMRI = Functional Resonance Imaging

HiIMG+HiPND = High Imageability, High Phonological Neighborhood Density

HiIMG+LoPND = High Imageability, Low Phonological Neighborhood Density

LD = Lexical Decision

LINGUA = Language Independent Neighborhood Generator of the University of Alberta

LoIMG+HiPND = Low Imageability, High Phonological Neighborhood Density

LoIMG+LoPND = Low Imageability, Low Phonological Neighborhood Density

msec. = Milliseconds

NAM = Neighborhood Activation Model

NorKompLeks = Norsk Komputasjonelt Leksikon

NoWaC = Norwegian Web as Corpus

PALPA = Psycholinguistic Assessments of Language Processing in Aphasia

PET = Positron Emission Topography

PN = Picture Naming

PND = Phonological Neighborhood Density

RT = Reaction time / Response time

SLI = Specific Language Impairment

SLIP = Spoonerisms in Laboratory Induced Predisposition

TOT = Tip-of-the-Tongue

UEN = Urban East Norwegian

VLD = Visual Lexical Decision

WA = Wernicke's Aphasia

WS = William's Syndrome

1 Introduction

For many linguists studying language use, two general questions are of main interest: How do we store words in the mental lexicon, and which factors influence lexical access? The general goal of this thesis is not to answer the first question, but to look at two factors that may influence language access and processing. Many factors, such as a word's phonology, morphology, or semantics, may affect how easily a word is retrieved from the mental lexicon. This study will look at one purely semantic and one purely phonological factor, imageability and neighborhood density respectively, and see how these affect lexical access in an experimental context. Imageability, one of many semantic properties pertaining to a word, is the ease of which a word gives rise to a mental sensory image, and phonological neighborhood density is used to describe how similar sounding words are.

Because the relationship between a word's meaning and form is arbitrary (Saussure, [1916] 1983), one cannot expect a consistent mapping between any given semantic feature and a phonological feature, but since both semantic (e.g. imageability) and phonological factors have proved facilitative during language processing in a number of earlier studies (see chapter 2.4 on previous research). It is both relevant and important to investigate if the two properties of a word are equally facilitative the retrieval of single words from the mental lexicon.

Naming is primarily a semantically driven task and the major competition during production of single-word utterances are lexical items that are closely related to the target word in meaning. Higher phonological neighborhood density (PND) does, however, strengthen the activation relative to semantically related words (Middleton and Schwartz, 2010, 405). With that in mind it would be relevant to see how semantics and phonology interact during speech production and perception. As mentioned, the two factors I will look at are imageability, how easily a word gives rise to a mental image, and phonological neighborhood density, how many words that are similar-sounding to a target word. For instance, I would like to investigate whether high imageability words from dense phonological neighborhoods behave differently than low imageability words from sparse phonological neighborhoods.

Reilly and Kean (2007) found that several cognitive processes regarding language and language use showed shared effects of phonology and imageability. Some of these processes were speed of lexical access, vocabulary size, reading latencies and verbal memory. They took this as evidence for interactions between a word's semantics and phonology, and encourage researchers to continue studying the shared effects of semantics and phonology.

To study the relationship between language and the brain, researchers have often studied the language use observed in persons suffering from different kinds of language deficits, among them aphasia; a focal, acquired language injury commonly associated with stroke. The rationale behind studying the language use of informants with an acquired language deficit is that the brain has been fully matured and stable before the injury, which means that the language deficits probably are connected to the damaged areas in the brain (Obler and Gjerlow, 1999).

1.1 Thesis outline

In the next chapters I will describe what phonological neighborhood density and imageability are, and also investigate the claim that these factors interact in language processing. To be able to do so, I will start out with a short introduction to imageability and phonological neighborhood density effects, respectively (chapter 2.1), before I take a quick look at speech perception and production in chapter 2.3, and discuss some alternative models of speech processing. In chapter 2.4 I move on to describe some previous research on semantic and phonological interactions in speech production and perception, especially research that focuses on imageability and neighborhood density.

A more thorough discussion of different theoretical frameworks on speech production and perception and their implications for this study is found in chapter 3 and my research questions and some general predictions will follow at the end of this chapter. In chapter 4 I will elaborate on the methods used in data collection both when it comes to building a wordlist containing imageability and phonological neighborhood density (PND) information, and for creating the experimental tests used to gather information about imageability and phonological neighborhood interactions in speech production and perception. The results of the tests will be discussed and analyzed in chapter 5.

In the last chapter I will draw some conclusions from my results, and discuss which theoretical framework is best suited for explaining my results, as well as address some issues for further research.

2 Background

Many researchers describing lexical access and speech processing have done so looking at either phonological or semantic properties of words. So with Reilly and Kean's encouragement in mind, the road to deciding which semantic and phonological properties to study in relation to lexical access was short. Imageability and phonological neighborhood effects have been thoroughly studied for years, but rarely together.

In this chapter I will look briefly at what imageability and phonological neighborhoods are, and how we can see their effects in speech processing both in typical and atypical populations, and introduce how atypical language processing can give us insight into how typical processing works. A more thorough discussion of speech processing and why researchers within psycholinguistics often study atypical language use will follow in chapters 3 and 4.

2.1 What are imageability and phonological neighborhood effects?

2.1.1 Imageability effects

Imageability is defined as the ease with which one can form a mental image of a word or a concept (Paivio et al., 1968). Such measures are obtained by asking informants how easily a word gives rise to a mental image. Imageability effects are described as the relation between how easily a word is accessed in the mental lexicon and its imageability rating. Generally speaking, high imageability words are accessed more easily and accurately than low imageability words. Since most high imageability words denote concrete objects, there is often a correlation between concreteness and imageability, but this is not always the case. For instance, *armadillo* is a concrete noun, but not necessarily a highly imageable one (Bird et al., 2001, 74). In the Norwegian imageability material that forms the basis for this thesis (Simonsen et al., In press), there are examples of concrete nouns that are low in imageability, for instance *planteskje* 'gardening trowel', which is by all means concrete, received a fairly low imageability score, and abstract nouns, such as *engel* 'angel' that was rated by most participants as a highly imageable noun. Many researchers do not distinguish between imageability and concreteness, and use the two terms interchangeably.

According to the dual-code theory (Kroll and Merves, 1986), a theory suggesting that lexical memory exist of two distinct systems (so called "codes") – one verbal and one visual code, one reason for high imageability words to be accessed more easily and produced more accurately than low imageability words could be the fact that they are coded both verbally and visually in memory. Since two codes in memory are better than one, high imageability words have an advantage in word selection (Kroll and Merves, 1986).

2.1.2 Phonological neighborhood density effects

Phonological neighborhoods serve as a means to describe how similar sounding lexical items are in a given language. Words are, phonetically speaking, neighbors if they differ in one sound only, either through substitution, deletion or addition (Vitevitch and Luce, 1999). This means that the Norwegian word *katt* /kɑt/ 'cat' has the words *hatt* /hɑt/, *kott* /kɔt/, *kan* /kɑn/, *skatt* /skɑt/, and *at* /ɑt/ 'hat', 'closet', 'can', 'treasure' and 'that' amongst its 35 neighbors. Although two words may share the same neighbor, they do not necessarily need to be each other's neighbors, as seen by examples such as *at* 'that' and *skatt* 'treasure' above. Words residing in dense neighborhoods (i.e. with many similar-sounding words) are produced faster and more accurately than words from sparse, or narrow, neighborhoods. In speech perception, on the other hand, the story is quite different. Words from high-density neighborhoods have many competitors, and are therefore recognized more slowly than words from low-density neighborhoods (Luce and Pisoni, 1998, Middleton and Schwartz, 2010). Phonological neighborhood density is of course not the only measure of phonological similarity, another one being so-called "cohorts", which is a collection of words that share the same initial onset. *Katt* 'cat' and *kall* 'calling' are phonological neighbors that belong to the same cohort, whereas *katt* and *kott* 'closet' are phonological neighbors from different cohorts. Some researchers write about cohorts and phonological neighborhoods as if they were the same.

2.1.3 Concreteness and cohorts

A word's semantic and phonological properties can be measured in a number of ways, for instance through imageability and phonological neighborhoods. One semantic property is imageability, but as already mentioned earlier the term concreteness is sometimes used instead of imageability. To obtain information about a word's imageability informants are asked to rate to what degree a word gives rise to a mental sensory experience. To judge a word's concreteness, on the other hand, informants are asked whether or not they can touch or feel the object the word is referring to. More often than not there is a correlation between concreteness and imageability in the sense that concrete objects are more easily imagined than abstract objects. Although imageability and concreteness behave in a similar manner in speech production and perception, they are not the same and should not be equated. However, some researchers (i.e. (Kroll and Merves, 1986, Westbury and Moroschan, 2009) do not distinguish between the two and use the terms interchangeably.

When Paivio et al. started collecting imageability and concreteness data for nouns to identify the differences between concreteness and imageability, they included words such as *shadow*, *phantom* and *ghost* because they thought these abstract words would provide interesting possibilities with regard to imageability and concreteness ratings, which can be seen in the results of their ratings. *Ghost* scored relatively high (5.37 on a seven point scale) but had a concreteness rating of 2.97 (also on a seven point scale) – which shows that words can be highly imageable without being concrete (Paivio et al. 1968, 3).

In much the same way that imageability and concreteness are used interchangeably, one may often see the term cohorts used as if it was phonological neighborhood density (Tyler et al., 2000, Westbury et al., 2002). These two factors behave in a similar fashion during speech processing, but they are, in fact, quite different. A cohort is a collection of words that share the same onset in the first syllable, whereas words are neighbors if they differ in only one phoneme in any position of the word. The English words *ham* and *hat* are neighbors and they also belong to the same cohort. But also *cat* and *hit* are neighbors to *ham* (amongst others), and these belong to completely different cohorts.

In the rest of this thesis, imageability is used when discussing a word's imageability ratings, disregarding its concreteness, and phonological neighbors refer to words that differ in one sound only, whether they belong to the same cohort or not.

2.2 What can atypical speech processing tell us about normal processing?

When studying the mental representation of language, we can of course not physically go into the brain to look at the ongoing processes, although some imaging techniques, such as functional Magnetic Resonance Imaging (fMRI) and Positron Emission Tomography (PET), and measures of brain responses through Event-related Potentials (ERP) can paint pretty accurate pictures of how where in the brain speech processing takes place, and how it unfolds in real time. PET and fMRI are used to show the areas in the brain that are active during processing, and ERP map the time course of the processes. Other, far less invasive methods include studying the language use of persons suffering from an acquired language deficit, usually due to a brain trauma of some kind. Quite often such research is carried out by elicitation experiments where the aim is to see whether damage to certain parts of the brain can be paired with specific language deficits.

Acquired language disorders mean that the language was intact in the brain before the injury, and therefore can be compared to the language observed in the “normal”, unimpaired brain. It is believed that the deficits observed in speakers with an acquired language disorder, such as aphasia, reflect the underlying cognitive architecture consisting of subcomponents that may be selectively impaired (Meuter, 2009, 3).

One important issue in the study of aphasia in linguistics, is that the observed symptom patterns are linked to, and dependent on, the structure and organization of the unimpaired, normal cognitive system (Ellis, 1985, 108). For instance it is believed that if a speaker’s mental lexicon in selectively impaired, it could indicate that the intact mental lexicon is structured in subsystems. In chapter 4.2 I will look closer at the use of language data from speakers with aphasia within psycholinguistics.

2.3 Language processing

Language production and comprehension are two complex cognitive tasks that most people, given normal brain capacities and an unimpaired speech system, take for granted. We talk and listen quite effortlessly. It is near impossible to remember the time before we could speak or understand our first language. Language abilities are a given; we rarely stop to think about how they work. Still, language can sometimes be a struggle, especially for people suffering from a developmental or acquired language disorder.

Although language impairments are obstacles for the people they affect, they can often tell us something about how normal language processes work. Linguists studying the breakdown of language in individuals who have suffered from a focal brain injury to the language dominant hemisphere (speakers with aphasia), do this because they believe that if some aspects of language are impaired, and others not, that might tell us something about how language is organized in the normally functioning, unimpaired brain. This will be thoroughly discussed in chapter 4.2.

Speaking and listening are often thought of as mirror images of each other, but although there are many similarities, the two processes are quite different. Firstly, speaking requires both intention and effort before we are able to produce words, whereas a listener will be able to hear and understand a message in their first language nearly automatically. Secondly, listening is also a much faster process than speaking. It can take up to as much as five times longer to generate a word than to understand it (Griffin and Ferreira, 1994, 21).

2.3.1 Speech production

Speech production is a multilayer process that can be divided into three major steps: conceptualization, formulation, and articulation, as seen in Figure 1 below. In this and the following paragraphs I will mainly focus on the production of single-word utterances.

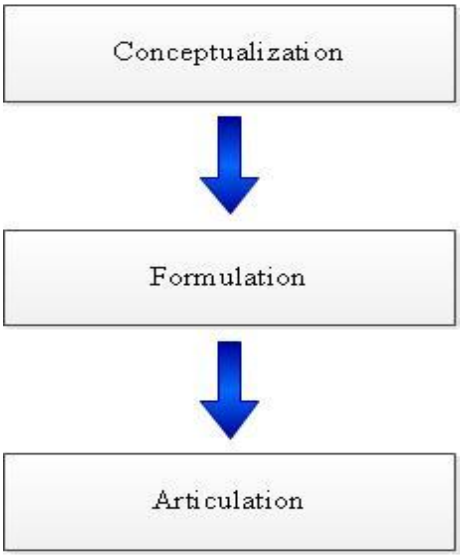

Figure 1: Three steps of speech production

First the speaker needs to decide upon an intention or a concept containing semantic and pragmatic properties that he or she wants to express, and also the situational constraints on how the content should be expressed (i.e. in a formal or informal register, which language to use etc.). This is the conceptualization stage, which is thought to be pre-linguistic and language neutral (Griffin and Ferreira, 1994). It is quite difficult to say anything specific about this first step because we know so little about the nature of ideas before they are put into words. Many psycholinguists and cognitive scientists believe that there exists a non-verbal representational system for concepts in the mind, a distinct non-verbal language for the concepts – a form of “mentalese”. Conceptualization is in short the mapping between these mental representations and lexical expressions for objects and events in the real world.

The notion of concept and conceptualization is not always straightforward. Lexical concepts are mental representations that are linked to word forms, but they are not word forms themselves; concepts can be seen as mental images, schemas, scripts or some other form of experiential knowledge that is organized in categories of thought and meaning (Jarvis, 2009, 101). Evidence from studies of bilingual speakers[1] suggests that the concepts may not be language-independent after all. It has long been believed that the mental lexicon of bilingual speakers consists of one set of concepts shared for both or all languages. This view has been challenged by researchers in the field of bilingualism in later years, putting forward evidence which shows that not all translation equivalents are also conceptual equivalents. Very often there is a relationship of partial (non-)equivalence between translations and concepts (Pavlenko, 2009). This can be seen, for instance, in how one category in a language can be divided in two categories in another, as with English *jealousy* which corresponds to both *misunnelse* and *sjalusi* in Norwegian.[2]

The second stage in speech production is formulation, which we can divide further into two steps: a word selection stage and a sound processing stage. In the formulation stage the speaker chooses the word, or words, in her vocabulary that best corresponds with the concept from the previous stage. Sound processing involves retrieving the individual sounds and constructing the phonological form for each word. Which words and sounds are chosen is language-dependent; if the situational context is a conversation in Norwegian, the words and sounds retrieved should be words and sounds in Norwegian. Now the speaker is ready to execute the third step of word production, and articulate the concept.

Exactly how these steps are completed is not certain, and there are different theories that attempt to explain how we as speakers go from one level to the next in order to convey a message, this will be discussed in greater detail in chapter 3.

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[1] The term bilingual is often used not only to denote speakers of two languages, but is also used to cover speakers of multiple languages, multilinguals.

[2] Pavlenko (2009) reports the same relation between Russian and English as Norwegian and English. *Jealousy* in English can refer to both intimate relationships and sibling rivalry (which is expressed by *sjalusi* in Norwegian and *revnost'* in Russian) and feelings of envy, as in “I am so jealous of your new car” where Norwegians would use *misunnelse* and Russian *zavist'* (Pavlenko, 2009, 135).

2.3.2 Different theories of speech production

The stages described above serve as a foundation for most models of speech production. The many theories of how the steps are followed from conceptualization to articulation can be divided into either serial or parallel processing. In serial processing models the steps follow each other independently one at the time with no interaction or overlap between one step and the next, whereas in the parallel models the steps all work together simultaneously and overlap with each other.

The differences between serial and parallel access models lie in how lexical items are activated in the mental lexicon. Serial, also called modular models are based on discrete activation, meaning that only one lexical item is activated, without activating similar items. Parallel models, however, claim that there is a constant interaction between similar lexical items, which will necessarily activate more than one lexical item at the time (Stemberger, 2004, 413). I will present one serial model and briefly look at parallel processing below, before I take a closer look at two different parallel models in chapter 3.1.

2.3.2.1 Serial models

Serial models for language processing are often based on computational evidence, where speech production events are processed rapidly in a serial manner, just as how things operate in computers (Carroll, 2008, 54). A speaker will need to finish one step in order to go on to the next. One example is Fromkin's (1971) model which suggests that there are six stages to speech production, each corresponding to a different level of linguistic planning. Based on a study of speech errors, or slips of the tongue, Fromkin proposed that a speaker needs to follow certain steps to generate an utterance (Fromkin, 1971), the following table is adapted from Caroll (1998, 199) and gives a schematic representation of the six steps in Fromkin’s model:

Stage 1	Generating a ‘meaning’ or ‘idea’ to be expressed.
Stage 2	The ‘idea’ or ‘meaning’ is structured syntactically, with semantic features associated with parts of the syntactic structure.
Stage 3	The intonation contour, where the placement of primary stress is generated.
Stage 4	Lexicon lookup: content words are retrieved from the mental lexicon and assigned to word slots.
Stage 5	Affixes and function words are retrieved and added to the “free” slots in the utterance.
Stage 6	The phonetic segments that make up the sentence are articulated according to phonological rules.

Table 1: The six steps of Fromkin's serial model for speech production (Carroll, 1998)

According to Fromkin's model, all six stages are independent of one another and do not interact. Her formulation suggests that different kinds of speech errors can manifest themselves on one level alone, for instance when content words change places during an utterance, it proves that the error occurs only at stage 4, as in Fromkin's example where sentence 1) was uttered instead of the more logical sentence 2):

1) Examine the horse of the eyes.

2) Examine the eyes of the horse.

Here only the content words are mixed up, and the rest of the sentence is intact, the stress pattern and syntactic structure are unaltered (Fromkin, 1971, 43).

Following this model, phonology and semantics are two independent levels of speech production, and effects from these levels (i.e. imageability and neighborhood density amongst others) will not interact. The semantic effects will manifest themselves before the concept receives its phonological shape. As both semantic and phonological factors have proven facilitative during lexical access, one might expect that these also operate on two different levels, first semantics and then phonology. This might suggest that it is easier to retrieve a word correctly from the mental lexicon if factors on more than one level that facilitate retrieval of that word. An overview of Fromkin's model can be seen in Figure 2 (below).

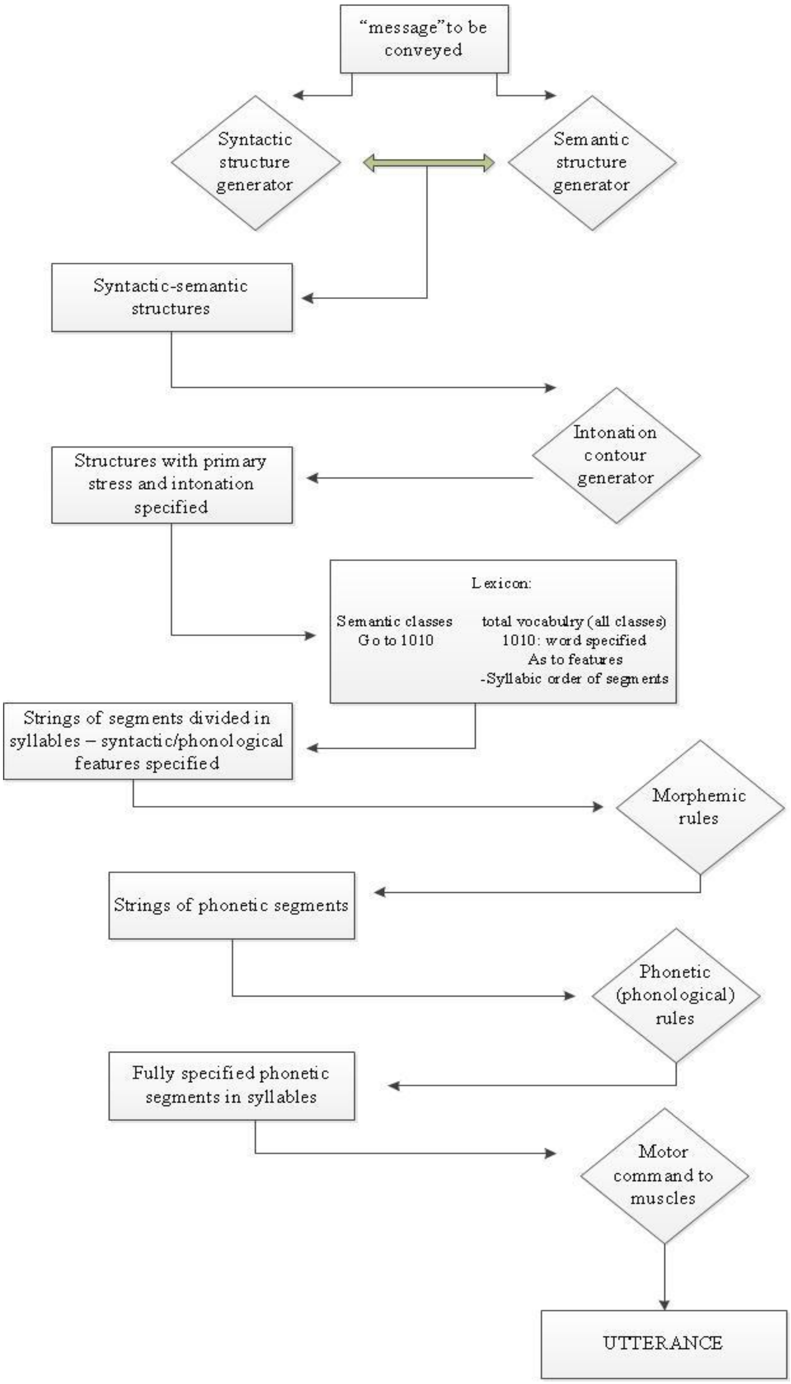

Figure 2: Fromkin's serial model of speech production, adapted from Fromkin (1971; 50)

2.3.2.2 Parallel models

Alternative to serial processing, there are a number of parallel processing models of speech production. In these models the main assumption is that the multiple layers of processing operate together simultaneously during production. Parallel activation models are often based on neural evidence; this means that the developers of such models have been modeling speech processing on the vast amount of neural activity that occurs simultaneously in the brain. This is in contrast to serial models which are often modeled on computational evidence, as mentioned earlier (Carroll, 2008). Language processes are thought to interact by activating and inhibiting each other during processing in the same way that neurons affect other neurons in the vicinity, either through activating neighboring neurons, or through inhibiting a neighboring neuron from becoming active (Carroll, 2008, 55).

One important assumption in parallel models is that there is positive feedback between the different stages. Once a syntactic node is activated, it may spread its activation to a morphological node. For instance, following an example from Levelt (1991), when the word *reset* is activated on the syntactic level, it also triggers activation of the corresponding morphemes on the morphological level, which in turn spread activation to the phonological level activating the necessary phoneme nodes. Because of this feedback between the stages, it is assumed that the morphemes will spread activation to other words containing the same morphemes, for instance *resell*, which spreads some of its activation on to *sell*, and ultimately to the phonemes /s/, /e/ and /l/. The interaction between the different levels of speech production will necessarily activate multiple entries in different nodes, but this activation is exponentially decreased over time, as more of the target word becomes available for processing, until the activation is reduced to zero (Carroll, 2008, 115).

Because activation can spread in all directions between the nodes, one can expect to see competition between the activated nodes, where the node with the strongest activation eventually will win. As imageability and phonological neighborhood density are two factors that have been proven to influence speech processing, one would expect these factors to affect the activation on the semantic and phonological levels respectively. Two models of parallel access will be outlined and discussed in the next chapter.

2.3.3 Speech perception

Under normal circumstances speech is perceived towards a background of other noises, and still we manage to focus our attention on one single input stimulus – the meaningful speech sounds that make up words. All other auditory signals compete with speech sounds, which present the listener with a certain difficulty in perceiving what is being said. This problem of perceiving sounds of interest, mainly speech sounds, is dubbed “the cocktail party problem”, a term coined by Cherry (1957), and stems from the difficulties of hearing, and understanding what is being said in particularly noisy environments, like cocktail parties.

As with speech production, the process of speech perception, though not comprehension can roughly be divided into three levels. These three levels are not the same as in speech production; for perception the three levels are one auditory level, a phonetic level and a phonological level, as seen in Figure 3 below.

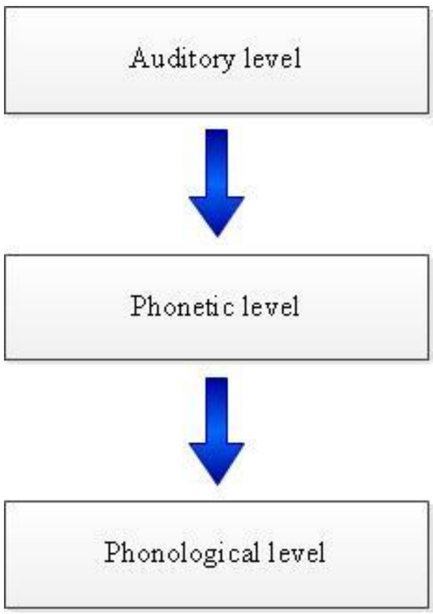

Figure 3: The three levels of speech perception.

As with speech production there are different theories on how we perceive and understand speech. It is reasonable to believe that we perceive speech sounds in a parallel manner and not one sound at the time since there is no physical break between the different sounds in a syllable. Furthermore, co-articulation and reduction are other factors that make it hard to presume that we perceive sounds one at a time. Upon hearing a sound, the brain is already tuned in for the next couple of sounds, and because it is not coincidental which sounds that follow each other in a given language (based on phonotactic constraints and rules), the brain makes an estimated guess, well supported by context, on which sounds will follow, and ultimately which word it just perceived. A next step would be for the brain to make sense of those words, comprehension, but a discussion of that does not fall within the scope of this thesis.

All sounds we perceive, linguistic and non-linguistic, are first dealt with at the auditory level; where we discriminate between meaningful speech sounds and other incoming auditory stimuli. Speech perception is viewed as the recognition of complex acoustic patterns camouflaged in other noise. The phonetic and phonological levels are specific for language perception, and only sounds we recognize as speech sounds move on to these two levels. At the phonetic level the speech sounds are identified as such, and at the phonological level phonological rules are applied to the speech segment. At this point we recognize the incoming stimulus as meaningful speech in a particular language (Carroll, 2008, 70). As mentioned there are different views on how we perceive language, and this will be more thoroughly outlined and discussed in chapter 3.2.

2.4 Previous research

Both imageability and phonological neighborhood density (PND) have proven facilitative in speech production and perception in neurologically healthy speakers and speakers with aphasia. These factors have been studied extensively separately, but because many theories of lexical access in speech production and perception assert that there are separate modules for semantics and phonology in the mental lexicon, there are not many studies that look at how these factors interact. When researchers have previously looked at the interactions between semantics and phonology in speech production, they have investigated how semantics may influence phonology or vice versa. I have not been able to find any study examining imageability and phonological neighborhood density effects together in speech production. When it comes to perception there are two studies that look at imageability and phonological neighborhood density, but not quite in the same way as in this thesis.

The studies described below all look at how phonological neighborhood density and imageability are facilitative factors in naming, even for informants suffering from semantic or phonological deficits. They also, to some extent, address the interactions between the two factors in speech perception. These studies suggest that both semantic and phonological factors play a role in speech production, regardless of language impairment, but also that there is a reason to believe that the different factors interact and influence each other.

2.4.1 Imageability

Imageability, the ease to which a word gives rise to a sensory mental image, has been shown to have an impact on how fast and how accurately lexical items are retrieved from the mental lexicon (Paivio et al., 1968). Nouns are generally more imageable than verbs, adjectives and function words, and concrete nouns are more imageable than abstract nouns (Bird, Franklin and Howard, 2001, 2003). Although there is a strong correlation between a noun's concreteness and its imageability, the two are not the same, as discussed above in chapter 2.1.3. Concreteness is measured by asking informants to what degree they feel they can touch and hold the stimulus, whereas when rating imageability the informants are asked how easy or difficult it is to visualize or acoustically imagine a word. A concrete noun may score low on imageability, and all high imageable nouns are not necessarily concrete. Many authors use these two terms interchangeably, but here imageability is used to refer to each noun’s imageability score, as obtained by (Simonsen et al., In press), where there is no additional information about the word’s concreteness.

Prado and Ullman (2009) conclude that lexical items that are more easily imagined, are also more easily memorized and stored, which means that complex words that require composition should not show imageability effects in the same manner as stored words (e.g. English irregular verb forms, for instance English past tense forms). Another view is proposed by Strain, Patterson and Seidenberg (1995), who claim that the effects of imageability have proven stronger on low-frequency words and exception words than on high-frequency regular words. Imageability effects are also found for words with weak orthography-to-phonology mapping in reading exercises, and in aphasic patients whose speech is characterized by phonological errors; this could be because meaning plays a more prominent role when the orthography-to-phonology mapping is weak (Strain and Herdman, 1999, Strain et al., 1995).

Strain et al. (1995) predicted that normal adult readers’ accuracy and speed of word naming should show interaction between frequency, regularity and imageability. Regularity was defined by two criteria: the pronunciation of the word should be consistent with grapheme-to-phoneme rules, and the word should belong to a consistent orthographic neighborhood. In English *bank* is said to belong to such a consistent orthographic neighborhood because all *_ank* words rhyme, but *barn* does not belong to a consistent neighborhood, because some words, like *warn* does not rhyme with the other *_arn* words and thus breaks with the orthography-to-phonology mapping of this neighborhood (Strain et al., 1995).

Their informants were significantly faster at naming high-frequency words than low-frequency words, regular words had shorter response latencies than exception words (i.e. words with an irregular orthography-to-phonology mapping), and high imageability words were also named in less time than low imageability words. There was also a significant interaction between frequency and regularity, but not with imageability. Although this effect was not significant, low-frequency exception words showed a higher effect of imageability than high-frequency exception words. Neither high- nor low-frequency regular words showed any interaction between frequency and imageability, and they had roughly similar reaction times (Strain et al., 1995, 1143). An analysis of the errors in this word naming experiment revealed a significant imageability effect on the low- frequency words, but no effect on the high-frequency exception words: more regularization errors[3] were made to low imageability rather than high imageability words. These results show that normal adult readers are slower and less accurate at producing low imageable, low-frequency exception words than low-frequency exception words with higher imageability ratings.

Because the interactions between regularity, frequency and imageability were not as pronounced as first predicted, Strain et al. designed a second experiment, only looking at low-frequency exception words, to see if they could replicate the findings, but with clearer evidence. Again, they found that normal adult readers showed a reliable interaction between regularity and imageability in both response latencies and accuracy. A third experiment, consisting of the same dataset, was conducted to see whether speeded naming would result in a reduced effect of word imageability. The results show that when forcing participants to speed up their word naming, more regularization errors were made on high imageability exception words, whereas there was no effect on the regularization errors on low imageable exception words, which they take to mean that semantic information facilitates the correct naming of high imageability, low-frequency exception words (Strain et al., 1995, 1150).

Berndt, Haendiges, Burton and Mitchum (2002) looked at grammatical class and imageability in aphasic speech production, where they tested seven aphasic informants on action and object naming, as well as oral reading and sentence completion and compared their

[3] A regularization error is an error where the participant pronounces an exception word as if it was regular. For instance pronouncing *pint* as if it rhymed with *mint*.

results to nine normal control subjects (Berndt et al., 2002, 355-356). The control subjects showed no difference in naming accuracy for nouns and verbs, but five of the seven aphasic informants showed significant differences in production of verbs and nouns in an object/action naming task. Three of these five informants also demonstrated significantly more difficulties in producing low imageable words. The two last informants showed no significant difference in the action/object naming task, but did however score significantly lower on reading words that were low in imageability (Berndt et al., 2002).

A more thorough analysis of the individual results suggests that the effects of imageability and grammatical class are independent of each other. The claim is supported by evidence from their group analysis where the grammatical class effect (nouns were easier to name than verbs) was maintained even when noun/verb imageability was equated. Furthermore, the informants who showed sensitivity to imageability did not have more problems producing verbs than nouns. Another finding was that even if an informant showed poor retrieval of low imageability verbs, this was not necessarily indicative of poor retrieval of all low imageable words. This was especially apparent in one informant (BN) who mostly made mistakes when producing verbs of low imageability. Because he showed much higher accuracy when producing low imageable nouns than low imageable verbs, Berndt et al. claim that the imageability effect cannot explain the verb deficit (Berndt et al., 2002, 364-365). This means that although verbs are less imageable than nouns, there is not necessarily a shared effect of grammatical class and imageability.

Hanley and Kay (1997) tested how semantics affected naming in a patient prone to phonological errors. Imageability proved positive on their patient's (PS) speech production. PS was prone to phonological errors, both in spontaneous speech and in repetition, but showed fewer phonological errors on high imageable words (Hanley and Kay, 1997). PS reported that he "used the meaning of the word or a mental image to help him with [remembering] longer words" (Hanley and Kay, 1997, 1071). He made significantly fewer phonological mistakes on high imageability words than on words that were low in imageability. Almost all of the errors reported in PS' speech were phonologically related errors, and there were no reported semantic errors during testing.

In a later study Hanley, Kay and Edwards compared PS' results to another patient (MF) who showed similar performance patterns as PS. The comparison proved that both informants showed imageability effects in auditory repetition and in writing. Further, they made phonological rather than semantic errors when repeating words and they showed impaired abilities to repeat non-words. Their performance on auditory lexical decision was normal, but they made phonological errors on different tasks, involving spoken production of familiar words, reading and picture naming. They were both significantly better at written than oral picture naming, and they both got more items correct in auditory repetitions than in picture naming tasks, which serves as a strong foundation for the authors' comparison between the two patients (Hanley et al., 2002).

The observed imageability effects in repetition indicate a lexicalization problem rather than impairment at the conceptual representational level, which can be used to support the claim in the literature that imageability effects in many cases are associated with lexicalization problems.

All these studies show that imageability may help speed up, and facilitate processing under many circumstances. We have seen that imageability affects the naming latencies and accuracy of low-frequent and exception words (Strain et al., 1995), both verbs and nouns, although independently (Berndt et al., 2002), and facilitates naming in aphasic speakers (Hanley et al., 2002, Hanley and Kay, 1997).

2.4.2 Phonological neighborhoods

Phonological neighborhood density (PND) is defined by the number of words that differ from a target word by exactly one phoneme through substitution, omission or addition. According to the substitution requirement *cat*, *hit* and *ham* are all phonological neighbors of *hat,* further *hats* and *at* are also neighbors of *hat,* based on addition and omission respectively. A word's neighbors do not need to be each other's neighbors (Middleton and Schwartz, 2010, 411).

Studies of phonological neighborhood density (PND) show that the effects behave differently in speech production and speech perception. Several studies of spoken word recognition have found shorter reaction times (RT) for words in low-density neighborhoods, than for words residing in high-density neighborhoods (Johnsen, 2010, Luce and Pisoni, 1998). The reason for this seems to be that words with a dense phonological neighborhood will activate more word decision units, which slows down the selection process, and result in longer RT in auditory word recognition tasks (Luce and Pisoni, 1998). The opposite seems to hold true for phonological neighborhood effects in speech production, where more neighbors show a facilitative effect. Words from high density neighborhoods are produced more quickly and more accurately than words from low density neighborhoods.

Middleton and Schwartz (2010) investigated the effects of PND on speech perception in three informants with aphasia; two who had phonological deficits and one informant prone to semantic errors (indicating a deficit in the mapping from semantics to words). Both the informants with phonological deficits (P1 and P2), and the speaker with semantic difficulties (P3) showed greater accuracy in naming targets from high-density than from low-density neighborhoods, but P3 also made significantly fewer errors with words with high PND than on words with low PND.

They tested the informants in three different experiments. The first experiment was designed to collect data from P1 and P2, and they compared the results from this first study with P3's performance in the next two experiments. Both P1 and P2 were prone to phonological errors in naming, but showed greater accuracy in naming words with high PND and produced more phonologically related errors in words from low-density neighborhoods. Phonologically related errors are errors that were recognized as phonologically related to the target word, for instance if the informant produced /h/ instead of /k/, and therefore erroneously producing “hat” for “cat”. Other phonologically related errors are errors that resulted in a phonologically related non-word (Middleton and Schwartz, 2010, 412). To be recognized as phonologically related to the target, the non-word shared at least one phoneme in the same position as the target, or two phonemes in any position.

The two remaining experiments were designed to test another informant with aphasia, this one prone to semantic errors in naming (P3), and to test the effects of PND on semantic processing. The authors assumed that neighborhood density would influence the mappings between semantics and words, and that P3 therefore would demonstrate greater accuracy in naming targets from high-density neighborhoods. In P3’s first experiment, experiment number 2 in the study, P3 showed a significantly lower rate of semantically related errors (i.e. substitution of the target noun with a synonym, a category coordinate, superordinate/subordinate, or a strong associate) on targets from high-density neighborhoods, demonstrating a phonological neighborhood density effect on the mapping between semantics and words.

In the last experiment the authors tried to replicate the influence of PND on P3's naming performance, but with a different set of materials. Because of the similar findings in the two experiments they tested P3 on (experiment 2 and 3), Middleton and Schwartz concluded that it is likely that the effects of PND on P3's naming performance is due to the impact of phonologically related neighbors on word selection rather than on conceptualization.

Vitevitch (2002) looked at the effects of PND on speech production in non-language impaired speakers, and tested them on picture naming and speech-error elicitation. For each test he used different materials and informants, yet the results were strikingly similar. His hypothesis was that words residing in dense neighborhoods get more activation from formally related neighbors in the lexicon, which facilitates the retrieval. Words with few phonological neighbors will not get the same amount of activation, and will be slowed down in retrieval which in many cases can result in a tip-of-the-tongue (TOT) state, where the speaker knows the word form, but is unable to produce it (Vitevitch, 2002). The methods used to induce slips of the tongue were the SLIP technique (spoonerisms[4] of laboratory induced predisposition) and tongue twisters. Both the tongue twister task and the SLIP task elicit speech errors by activating competing speech plans.

In a SLIP test the participants are instructed to repeat to themselves a series of word pairs that are presented to them on a computer screen. The word pairs were of the type *pig – bull*, *pin – ban* which activates a /p/-/b/ speech plan. At a certain point the participants are asked to say a word pair out loud, but the initial phonemes of the words are now in reverse order, for instance *beach – palm*, (which is a /b/ - /p/ speech plan) which competes with the initial /p/ - /b/ speech plan and frequently result in speech errors. The results of this test showed that the participants produced significantly more speech errors on words from sparse rather than from dense phonological neighborhoods.

For the next experiment he developed 20 tongue twisters consisting of four words each with similar neighborhood density, half of them consisted of words from sparse neighborhoods and the other half of words from dense neighborhoods. The participants were asked to repeat each tongue twister six times as quickly as they could. More errors were reported on the tongue twister words from sparse neighborhoods than on the tongue twisters with words from dense neighborhoods.

In a picture naming test Vitevitch found that words from dense neighborhoods were produced faster than words from sparse neighborhoods, but there was no difference in accuracy. The results of these three tests taken together show that having multiple word forms

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[4] A spoonerism is an intentional or unintentional play with words, where the initial sounds of two or more words change place as in the erroneous production of *balm peach* for *palm beach*.

activated simultaneously in the lexicon leads to faster and often to more accurate production (Vitevitch, 2002, 741).

When it comes to perception, it has long been argued that words with many similar sounding neighbors compete with each other during processing, which means that neighborhood density behaves in quite different ways in production and perception. This has been discussed by, amongst others, Janse (2009) who studied neighborhood density effects in auditory processing of non-words in speakers with aphasia. She found that, just as with real words, non-words need to be compared to the existing items in the lexicon, which will take longer time if the non-words have many real word neighbors to compete with (Janse, 2009).

Her material consisted of 80 monosyllabic CVC non-words based on Dutch phonotactics, 40 with a low number of real-word neighbors (10 or less), and 40 with a high number of real-word neighbors (16 or more), and 80 monosyllabic real Dutch words to balance for lexical status. She tested 27 speakers with aphasia, 15 with a non-fluent type of aphasia and 12 with a fluent type (more on different aphasia types in chapter 4.2.1), and ten control subjects in a lexical decision test where the informants had to respond to whether or not an auditory stimulus was a real Dutch word or not.

She found that in addition to how neighborhood density significantly affected the accuracy and response times given by all informants, the aphasia type also played a role in the processing of non-words: overall accuracy for the non-fluent group was 88 % whilst it was only 79 % for the fluent group, this difference was statistically significant. Overall the non-words with few phonological neighbors were responded to faster and more accurately than the words with many phonological real-word neighbors (Janse, 2009, 201).

That all three groups showed the same main result is taken to mean that more phonological neighbors pose a problem for lexical recognition in both aphasic and normal subjects. The inhibitory effects of phonological neighborhood density in speech perception will be discussed in chapter 3.2.1.

2.4.3 Imageability and phonological neighborhoods

Although there are many studies looking at interactions between semantics and phonology, studies that examine the factors of imageability and phonological neighborhood density in language processing are scarce. Still few researchers have tested the claim that a purely semantic factor, imageability, might have an impact on phonology. Most of the studies I have found have looked at either phonological neighborhood density or imageability in relation to semantic or phonological processing without necessarily including the other factor.

Camarata and Schwartz (1985) found that semantics influences phonology in language acquisition, especially when looking at word type. Their study shows that action words, which are associated with increased semantic and cognitive complexity compared to object words, are less accurately produced than object words (Camarata and Schwartz, 1985, 325). Cortese, Simpson and Woolsey (1997) report a similar finding, namely that phonological generation is facilitated by semantic information in the target, for instance imageability (Cortese et al., 1997, 229).

The study by Cortese et al. was designed to investigate the semantics-phonology relationship in naming. By conducting a priming experiment they wanted to see if imageability influenced phonological mapping. They found that low imageability words were named more slowly than high imageability words, and that there was a significant interaction between imageability and regularity of the words on subject level: high imageability irregular words were named faster than low imageability irregular words. They take this to support the claim that activated information at the semantic level will play a greater role in processing when the generation of the phonological code is difficult. They further argue that this is a sign of interactive activation in lexical processing, because the activity from each level of processing (phonological orthographic, and semantic) is affected by the activation of the other levels (Cortese et al., 1997, 229).

In one study of spoken word recognition, Tyler, Voice and Moss (2000) found that repetition latencies were shorter for high imageability words than for words with low imageability scores in auditory processing. The imageability effect was only seen on words from large cohorts (i.e. words with similar sounding onsets in the first syllable), which indicates that both the semantics and the phonology of a word are active and interactive during processing.

In the cohort model it is believed that the neighborhoods consist of a “cohort” of words that share the same incoming stimuli, usually defined as the same onset in the first syllable. As more of the stimulus is perceived the cohort shrinks until the target word is distinguished from the other competing words (Dell and Gordon, 2003). This is in many ways similar to the Neighborhood Activation Model described in 3.2.1 below.

Tyler et al. (2000) believe that there is a continuous interaction between phonology and semantics for all words, but that semantic information plays a larger role as the discrimination process in speech perception becomes more difficult, for instance in contexts where the phonological neighbors, or in their case cohorts, hinder the recognition of a stimulus word.

They tested 30 non-language impaired subjects in lexical decision (LD) and repetition. 14 subjects were tested in LD and the remaining 16 were tested on repetition. The results from the two tasks were strikingly similar, despite the different information groups. High imageability words were repeated faster and more accurately than low imageability words in the repetition task, and they also had much shorter LD response latencies than low imageable words in the lexical decision task. The strongest claims for an interaction between meaning and sound could only be made if the two tasks showed similar result patterns. When controlling for cohort size, imageability effects were only significant in words from large cohorts. This could suggest that when the phonology-to-semantics mapping is difficult, i.e. when the competition between the different members of the cohort is strong, such as when words are members of large cohorts with many high-frequent candidates, semantic information can help in the discrimination process (Tyler et al., 2000). Their results support an argument that recognition of spoken words is depending on a system of speech perception that is interactive, with constant communication between phonology and semantics.

Westbury and Moroschan (2009), who do not distinguish between imageability and concreteness, suggest that concrete (high imageable) and abstract (low imageable) words should show a systematic difference in the number of phonological neighbors. They further claim that the phonological processing fluency should predict the size of the interactions between imageability and phonology. One of their main claims is that abstract words are represented in the mental lexicon in a way that makes them more sensitive to phonological factors (Westbury and Moroschan, 2009).

They did not find a reliable interaction between concreteness (imageability) and phonological neighborhood density similar to the results reported in Tyler et al. (2000), in their visual lexical decision (VLD) test, and thought that maybe Tyler et al.'s use of cohorts rather than phonological neighborhoods could explain the different results. Even when they calculated the cohort sizes for their material they were not able to reproduce the results of Tyler et al. They did, however, find that reaction times (RT) correlated with abstract words but not with concrete words, and also that there was a difference in the modality of stimulus presentation. When the targets were presented visually (i.e. written words on a computer screen), there was no interaction between concreteness and neighborhood density, but in auditory presentation there was a reliable effect of phonological neighborhood density on abstract words, although not on concrete words. Similar results were found in three different experiments: lexical decision, semantic decision and a rhyme-priming experiment. They attribute their findings to a hypothesis which claims that concrete and abstract words are represented differently in the lexicon, and that abstract words are represented in a way that makes them more prone to phonological factors than concrete words.

A word's semantics will potentially affect the lexical access of all word classes, but the effects are more pronounced on the naming of low-frequency words, especially low-frequency irregular words, or words with many competitors in perception. Based on the results from previous research, it seems like semantics plays a more prominent role in both production and perception of words that are, for some reason, phonologically difficult. When investigating the effect of semantics on phonological encoding, imageability can be chosen as a semantic variable due to previous research displaying the significant effect on naming abilities in patients with phonological deficits, where naming is mediated mainly by semantics (Strain and Herdman, 1999).

3 Theoretical background

In this chapter I will outline two models of speech production and two models of speech perception and discuss their predictions with regard to imageability and phonological neighborhood density. Towards the end of this chapter I will outline my research questions for further discussion.

3.1 Theories of speech production

In chapter 2.3.2 I outlined the general differences between parallel and serial models of speech production. Still the picture is more complex than that; there is not just one parallel and one serial view of language processing. There are many different directions within the two traditions. In this chapter I will focus on two different parallel models for lexical access in speech production, one following the so-called logogen view, the other following the connectionist view.

The two models are limited to the production of isolated words, not sentences, which makes them suitable to use as theoretical models for the present study because the focus here lies on single word production and perception.

3.1.1 Lexical access

The two models presented below both look at the process of retrieving words from the mental lexicon and preparing them for speech production. The process of activating the right concept, retrieving its syntactic, semantic and phonological properties, and making it ready for articulation, is known as lexical access in speech production. In speech perception, lexical access refers to how a word is recognized at the auditory level and then again at the phonological and phonetic levels. Although we go through these steps several times a day, and most of us quite effortlessly, lexical access in production and perception are not a straight-forward operations, which may explain why there are so many different models trying to describe how we go about when producing and perceiving language.

There are many factors that may influence the retrieval of a lexical item from the mental lexicon. First of all one can say that different lexical forms can be associated with the same concept (Denes, 2011). For instance the same object can be named *flower* or *rose*, depending on the level of specification needed. Other factors are age of acquisition, frequency, grammatical class, and perceptual qualities and/or phonological make-up of the referent, the two latter which are of most interest for the further discussion.

3.1.2 Levelt's model for lexical access in speech production

The logogen theory was originally developed as a general theory of lexical access, covering both language comprehension and production, and most of the research within this theoretical framework has been conducted on speech comprehension. Levelt (1989) and Levelt, Roelofs and Meyer (1999), however, were inspired by the logogen theory for their model of speech production. Since this is a strictly feed-forward model, it does not cover speech perception, but only production.

Within the logogen framework lexical items are represented as *logogens*, devices that collect evidence for the appropriateness of a word (Levelt, 1989, 202). The logogen system is a parallel accessing device as all logogens are simultaneously active in collecting their specific information. The information necessary for activating the logogens originates in a so-called Cognitive System, where all conceptual, syntactic and higher-order functions reside.

When the logogen has collected the evidence for a word's appropriateness, it makes the word's form available for use, which is called "firing". In short, this means that the logogen sends a phonetic code to the so-called Response Buffer and the activation level is reduced to zero. The Response Buffer can use the phonological code to either initiate a spoken response, or send it back to the logogen system. In case of the latter, the logogen will be re-activated and fire again, sending the same phonological code back to the Response Buffer, which will keep the phonological code active and available for use, even if it is not immediately uttered (Levelt, 1989). The parts involved in the generation of speech according to the logogen model can be seen in figure 4 below.

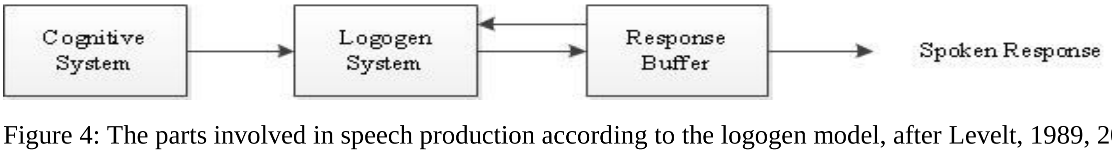

Figure 4: The parts involved in speech production according to the logogen model, after Levelt, 1989, 202.

In Levelt et al.'s model (1999) the production of words is seen as a stepwise process from conceptual preparation to the initiation of articulation, but it does not cover articulation. Each step takes a certain kind of input and creates an output representation, which serves input for the following level. A schematic representation of the model, its steps and output representations can be seen in Figure 5.

Many models of speech production are based on evidence from atypical speech, very often they are modeled on speech from speakers with language deficits, and spontaneous or induced speech errors. The model by Levelt and colleagues, on the contrary, is built on evidence from reaction time experiments from normal speakers. They argue that the model should after all represent the process of normal speech production, and should therefore not describe infrequent deviations from these processes. The model should, however, be able to account for speech errors as well as production latencies (Levelt et al., 1999).

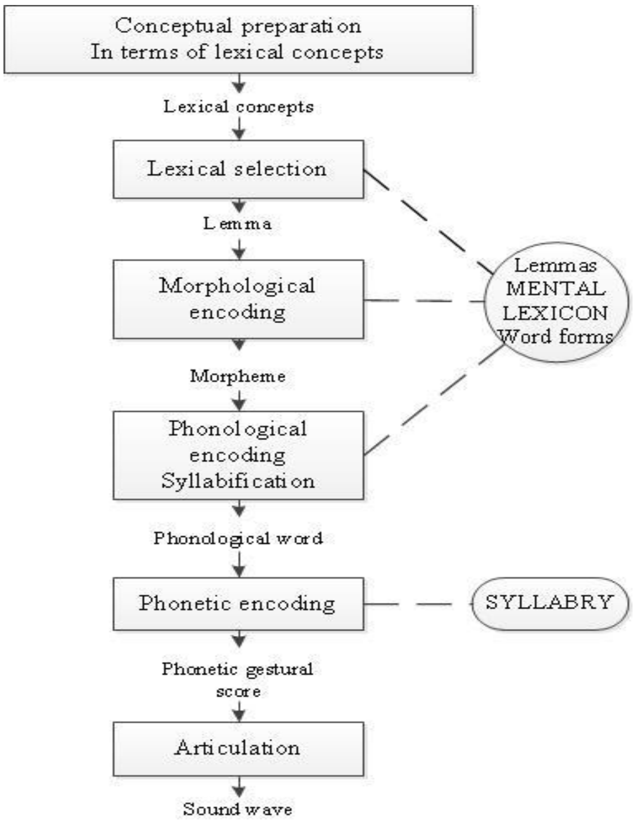

Figure 5: Levelt et al.'s model of lexical access in speech production (from Levelt et al. 1999:3).

The first stage of the model is called conceptual preparation, and the output representation is the lexical concept. At this stage the speaker does not only decide on which notion/information she wishes to express, but also on which lexical concept that best covers that notion. This is sometimes dubbed *the verbalization problem*. The speaker wishes to express a notion, but there may not be a suitable referent available since there is not always a one-to-one relation between a concept and a referent that covers that concept. For instance, if a speaker of English wishes to talk about a female horse, she can do so by activating the lexical concept MARE, which covers this notion, but if the intended referent was a female elephant, the speaker would probably prefer the phrase "female elephant" or "elephant cow" since there is no lexical concept that covers this notion in English (Levelt et al., 1999). Another related issue is what Levelt calls *perspective taking*. Depending on the context, lexical alternatives or even the task the speaker is asked to perform can influence which lexical item gets selected. For instance if the speaker is tested on an object naming task it might be just as "right" to name an object *animal* as *horse* or *mare*. (Levelt et al., 1999). The model also includes semantic reasons for activation by means of a conceptual network. In the network concepts will spread activation to semantically related concepts.

The second step in Levelt's model is the lexical selection level. This is where the speaker is retrieving a lemma (the output representation for this stage) from the mental lexicon. Although this process is very fast (speakers retrieve two or three words per second from a lexicon that contains tens of thousands of items), there are seldom errors originating at this level. Only one per thousand of speech errors are errors of lexical selection (Levelt et al., 1999, 4). This process is able to run so smoothly because of a level of lemma nodes in the conceptual network; the theory operates with one lemma node per concept. When a lexical concept becomes active it spreads some of its activation to the lemma node for that concept. The lemma with the highest activation is the one that will ultimately be selected, which in turn activates the lemma's syntax. A lemma's additional diacritic parameters are also activated. This means that for (English) verbs the features for person, number, tense and mood needs to be valued for further encoding (for Norwegian verbs, only tense and mood will have to be valued, as there is no person or number conjugation for Norwegian verbs); this step completes the selection of the syntactic word, and the speaker is now going from the conceptual/syntactic domain to the phonological/articulatory domain.

The phonological/articulatory domain starts off at the model's third level, which is the level for morphological level, with morphemes as the output representation. The morphemes serve as input to the fourth level, the level for phonological encoding and syllabification. Now the speaker has to prepare the appropriate articulatory gestures and prosodic context for the selected word, starting with retrieving its phonological form from the mental lexicon. This is not always as simple as it sounds, as evidenced when researchers frequently report on the so-called "tip-of-the-tongue" (TOT) phenomenon. The TOT state is the momentary inability to retrieve a selected lemma's phonological form. Levelt et al. (1999) report that speakers of

Dutch and Italian (and probably other gender languages, like Norwegian, too), know the grammatical gender of the target word although they are unable to retrieve the phonological form of that word, which indicates that the morphological information and phonological form belong to separate levels.

To access the word form, the speaker needs to activate more than only the right speech sounds. The word's morphological and segmental makeup as well as the metric shape of the word need to be activated before the word form can successfully be accessed. At this point there is no information about the word's syllable structure. According to this theory syllabification is a late process and not stored in the mental lexicon, because it often depends on the phonological environment of the word, and because syllabification in some cases can exceed lexical word boundaries (Levelt et al., 1999). The output representation of this stage is the phonological word.

After the morphological makeup and metric shape has been accessed and syllables assigned, the model moves on to the level of phonetic encoding. The model does not cover phonetic encoding in much detail, but focuses on how a phonological word's gestures are computed as the output representation. Levelt and colleagues assume that phonetic encoding entails the notion of a syllabary. The gestural scores for the most frequent syllables of a language are stored in a mental repository to which the speakers have direct access. This is an advantage as the speaker does not need to compose the right syllables every time she wants to use them, but can access the ready-made gestural patterns from the syllabary. The syllable scores are activated by segments of the phonological syllables. For instance, if an active /t/ is the onset of a phonological syllable (e.g. /tiŋ/), it will activate all other syllables in the syllabary containing [t]. As the syllables are successfully composed, the corresponding gestural scores are retrieved, which leads to the articulation of the phonological word (Levelt et al., 1999). The last step is articulation, and this is where the phonological word's gestural scores are articulated, but that is not the focus of this model.

One very important condition for this model is the aspect of self-monitoring. As this model does not cover articulation, self-monitoring might not present itself as an obvious feature of this model. But we do not only monitor our overt speech; evidence from spontaneous self-repairs show that we also monitor the internal representation of speech as it is being produced. The model is a feed-forward activation spreading model, as can be seen in the schematic representation of the model in Figure 5 (above). Feed forward entails that information from one level pass down to the next, but not in the other direction. Information that gets activated on one level cannot send its activation back to an earlier level.

3.1.2.1 Imageability and PND in Levelt's model

A main feature of this model is the feed-forward mechanism between the levels. This means that once a lemma is activated the information feeds forward to the morphological encoding, which again feeds forward to the phonological level and so on. There is no feed-back option, as there is in other parallel processing models, e.g. Dell et al.'s model presented below. This means that there is no option for later levels to influence earlier levels, so once a word's semantics is activated during lexical selection; it cannot be influenced by other, later processes such as phonology. The word's semantics may, however, influence the phonology because that is a later process. If both high imageability and high phonological neighborhood density are facilitative in word retrieval, words with both factors should be able to "pass" down in the system with greater accuracy than low imageability low PND words, because of the double advantage from the higher imageability and high phonological neighborhood density.

3.1.3 Dell et al.'s connectionist model of speech production

Within connectionist models, speech production, and other cognitive functions, are regarded as interconnected networks of several processors, rather than as one central processor (as in modular/serial models) or as a series of specialized processors (as the model proposed by Levelt et al.). This means that connectionist models can account for a large number of processes simultaneously (Caron, 1992, 173). One of the key assumptions of connectionist models is that linguistic information is represented in a distributed manner, which means that a lexical item is not seen as one unit representation, but rather as a pattern of activation across a set of shared units. There is also a constant interaction between those shared units, which is often dubbed interactive activation. Connectionist models are compatible with usage-based theories of language, as it is believed that in these models structures are not given in advance, but are shaped by the nature of the input it receives (Bybee, 2001).

The interactive activation is one of the main features in this model by Dell, Schwartz, Martin and Gagnon (1997). The connections in this model run both bottom-up and top-down, which allows for bidirectional connections between units of different types (semantic, lexical and phoneme units).

A second condition for Dell et al.'s model is that speech production is a two-step model. There is one step for lemma access, which in short is the mapping from concept representation to lemma, including semantic and grammatical information, but not phonological information, and one step for phonological access, which is the mapping from lemma to phonological form (Dell et al., 1997, 804). There are many reasons to assume that there are two steps in lexical access, an important one being that the arbitrary relationship between form and meaning motivates an intermediate step. Direct connection (so-called one-step mapping) between form and meaning would entail that phonologically similar words also should have some kind of shared meaning.

Evidence from speech errors can also be used to shed light on the two steps of lexical access. Lexical errors, or speech errors involving whole words, stem from problems at the level for lemma access, whereas speech errors that involve only the sounds of words are associated with phonological access problems. Here, as in Levelt's model, it is argued that the tip-of-the-tongue state can provide useful insights into the two steps. The speaker is able to retrieve the lemma, but the phonological access is unsuccessful, as seen when speakers of languages with grammatical gender know which gender a word has, but are unable to access the phonological form of the word (Dell et al., 1997).

Further, Dell and colleagues argue that lexical knowledge is integrated in a network with three layers, one semantic layer which represents the concepts, and which is connected to the lemma layer (or word layer) by excitatory bidirectional connections. This layer is again connected to a third layer, the phoneme layer, also by bidirectional excitatory connections (Dell et al., 1997). A schematic representation of Dell's model can be seen in Figure 6, below.

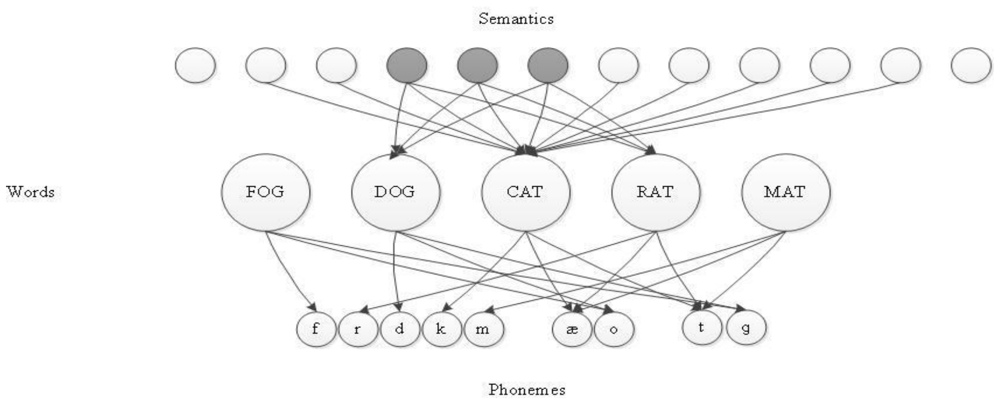

Figure 6: Dell's two-step interaction activation model for speech production (from Dell, 1997).

Following this model, in accordance with connectionist theories, each concept in the semantic layer is represented by 10 semantic feature units; the choice of 10 semantic features per word is arbitrary (Dell et al., 1997). When a speaker wishes to access one specific concept, all ten semantic nodes associated with that concept are activated. This activation will spread to the target word's semantic neighbors, which means that words such as *rat*, *mat*, and *dog*, will all be activated for the target word *cat* because they share semantic nodes with the target word. Lemma access is concluded when the most highly activated word from the right syntactic category is selected. The selected word sends a high jolt of activation onwards, which works as a starting shot for the next step: Phonological access.

This process is similar to the lemma access step. All nodes connected to the target word gets activated, and spreads its activation both forwards and backwards in the model, allowing all other nodes also connected to the target to receive activation. If we assume that the target word is still *cat*, during this spreading process the most activated phoneme nodes should be the ones that make up the word *cat*, namely /k/, /æ/ and /t/. These should be selected and linked to slots in a phonological frame that represents the structure of the word, including its number of syllables, stress pattern and the sequences of vowels and consonants within the syllables (Dell et al., 1997, 806). This model, as the one proposed by Levelt et al., does not cover articulation. It does, however, make a suggestion for what happens next. When the right phonemes have been selected, this will send jolts of activation to translate the phonemes into codes for articulation.

3.1.3.1 Imageability and PND in Dell's model

According to the model by Dell et al., semantics and phonology can potentially influence each other. When the semantics of a concept is activated, it will activate the appropriate phonemes to go with that concept. Multiple phonological forms can be activated simultaneously and influence the speed of naming and accuracy in speech production (Vitevitch, 2002). Because of the bi-directionality of this model, once the phonology is activated it will send some of its activation back to the semantic nodes until the most appropriate concept is chosen in terms of both phonology and semantics. It is therefore reasonable to suspect that words with both facilitative semantic (e.g. high imageability) and facilitative phonological (e.g. high PND) properties will be produced faster and more accurately than other words.

3.2 Theories of speech perception

In this chapter two different models of how we perceive single words are presented. The first model is mainly concerned with how we perceive and encode incoming phonological stimuli and the second model looks at the perception of words more generally.

Due to the inhibitory effects observed with phonological neighborhood density (PND) in speech perception, I will look briefly at why this effect behaves so differently in speech perception and production through the presentation of the first model of speech perception outlined below. I will also compare two possible theories of how language is perceived, to show that there is no unambiguous answer to how this process works. In the last chapter (chapter 6), I will discuss to what extent either of the theories will support my findings.

3.2.1 The Neighborhood Activation Model (NAM) of spoken word recognition

Earlier we identified three levels of sound perception: an auditory, a phonetic and a phonological level. However, speech is not usually perceived as individual sounds, but as a part of a larger context of syllables, words and sentences towards a background of other sounds and noises. All this contextual information influences the perception of the individual speech segments (Carroll, 2008).

The Neighborhood Activation Model (NAM) is based on the *Neighborhood probability rule*, which claims that the number and nature of a word's neighbors may affect the speed and accuracy of word recognition (Luce and Pisoni, 1998, 5). The model describes the effects of neighborhood similarity in the process of discriminating among acoustic-phonetic representations of words in the mental lexicon. The NAM, as many other models of speech perception, supports the view that word recognition is to a great extent a process of discriminating among competing lexical items (Luce and Pisoni, 1998). Following the NAM, words in the mental lexicon are structured in “similarity neighborhoods”. The activation of one word in the neighborhood will automatically stimulate, or activate, the other members of the neighborhood.

Upon hearing the stimulus input, all acoustic-phonetic patterns in memory are activated, regardless of whether they correspond to real words in the lexicon or not. This means that listeners are able to recognize novel words and non-words in addition to already known words in the concerned language. The acoustic-phonetic patterns then activate a system of word decision units tuned to the patterns themselves (Luce and Pisoni, 1998, 13). In contrast to the previous step, only acoustic-phonetic patterns corresponding to words in the lexicon will activate word decision units. These units, in turn, activate the higher level lexical information relevant to the words to which they correspond, both in long term and in short term memory (Luce and Pisoni, 1998). Because new words and non-words will not activate word decision units, it is not quite clear how listeners process new words in a given language. As the words do not carry any lexical information on the first occurrence there are no word decision units that correspond to the acoustic-phonetic patterns of new words. One theory is that the new words might be registered and stored, so that they can get activated the same way as already known words the next time they are encountered.

As the stimulus input is processed, the information regarding the match between the acoustic-phonetic pattern of the target word and the stimulus input increases, whereas the activation level decreases for lexical items that do not share the appropriate acoustic-phonetic mappings with the stimulus input. Both neighborhood density and the frequency of the neighbors will affect recognition of the stimulus word.

In the Neighborhood Activation Model, lexical representations will typically compete with, or at least inhibit each other during processing, which give rise to a logical explanation for why phonological neighbors are a negative influence. When a target word competes with its own neighbors during processing, it might be mistaken for one of the neighbors, or at least be temporarily distracted, which leads to longer reaction times or erroneous judgments (Dell and Gordon, 2003, 12). Figure 7 shows a representation of the Neighborhood Activation Model.

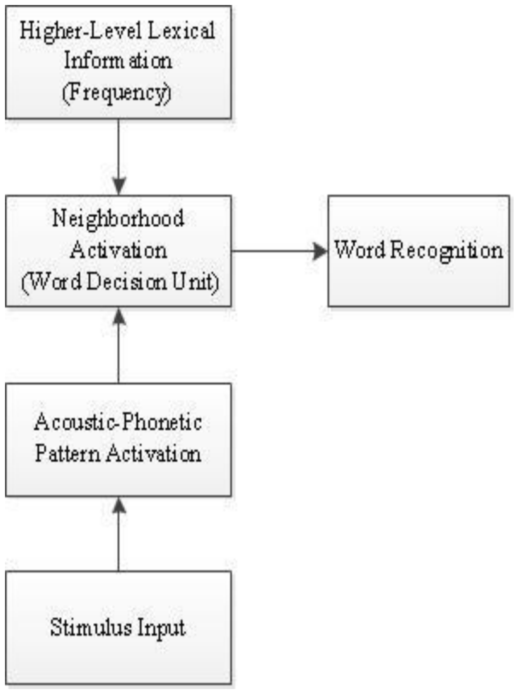

Figure 7: The Neighborhood Activation Model, from Luce & Pisoni (1998, 13)

3.2.1.1 Imageability and PND in the NAM

The Neighborhood Activation Model only covers phonology in spoken word recognition, and not semantics, which makes it difficult to predict how imageability might fit into this model. Although Luce and Pisoni write about lexical access, they admit that the term is a bit misleading within the scope of the NAM, because lexical information as it is monitored by the word decision units is only used to choose between activated acoustic-phonetic patterns, and is therefore not available to working memory. This means that the NAM, as it is outlined here, is an initial step in processing incoming stimuli, and the word decision units serve as stepping stones on to the higher levels of lexical information, such as semantics, syntax and pragmatics (Luce and Pisoni, 1998, 14).

Based on this I cannot make any predictions as to how imageability will fit this model, but when it comes to neighborhood density it predicts longer response latencies on high PND words in the lexical decision task both for neurologically healthy and language impaired informants.

3.2.2 A distributed model of speech perception

Gaskell and Marslen-Wilson (1997) found previous models of speech perception, which operate with ordered levels of information types, redundant. They argue that differences in speed or accuracy of retrieval of different forms of knowledge (i.e. phonological, semantic, lexical knowledge) could be modeled by partial activation of a distributed representation (Gaskell and Marslen-Wilson, 1997, 614), rather than through models based on one or more phonological levels that mediate between input representations and lexical items. Gaskell and Marslen-Wilson's model eliminates the intermediate levels, and sees lexical access as a direct mapping between the speech signal and both form and meaning of the word, based on a simple recurring network. This means that the lexical representations are distributed patterns of activity on a set of output nodes (Gaskell and Marslen-Wilson, 1997).

Following this model, lexical knowledge is represented as a set of features that encode information about both form and meaning of a word. Recognition of word forms is not a goal, but a product of this model. The network concentrates on retrieving lexical, phonological and semantic information, rather than on the explicit recognition of word forms. Gaskell and Marslen-Wilson try to explain the process of speech perception as a direct mapping from low-level feature information onto a distributed representation of lexical knowledge and form (Gaskell and Marslen-Wilson, 1997, 615). The key assumptions for this model are that all the different forms of lexical knowledge (i.e. semantics, phonology etc.) are represented in parallel and accessed simultaneously, and that speech input should map directly and continuously onto lexical knowledge.

The main difference between this model, and many other models of speech perception, like the NAM, is that this distributed model does not view the process of spoken word recognition as a process of competition between word candidates. Models like the NAM map speech input onto many localist representations, whereas Gaskell and Marslen-Wilson's model operates on a single, distributed level of representation. The model also claims that the process of lexical access should operate with maximal efficiency, which means that the model must derive the informative output available from the incoming speech signal. Only the relevant information should be extracted from the stimulus. If, or when, it is possible to single out only one lexical match to the stimulus input, all other information should be disregarded. The moment when there is a lexical match to the input is called "the uniqueness point of a word". If, on the other hand, more than one lexical item should match the input stimulus, the model should activate the stored knowledge of these candidates as well, but since the model assumes that speech is mapped directly onto distributed representations of lexical knowledge, multiple lexical candidates can only be assessed on this level of representation – and not on a separate level of competition.

When the network encounters multiple candidates for one input, the output of the network represents the set of word candidates compatible with the input *so far*. On the uniqueness point of a word, the set of candidates is reduced to only one word, but at other times the network has to hold up multiple parallel hypotheses until the disambiguating information is encountered. This competition-like behavior is observed when the network is unable to directly identify both phonological and semantic information provided by the input. Because this model integrates both the form and the meaning of a word, the network output should match only the representation of one word, whereas in other models where the lexical items compete during processing, two or more words can receive maximum activation. The model is illustrated in Figure 8 below.

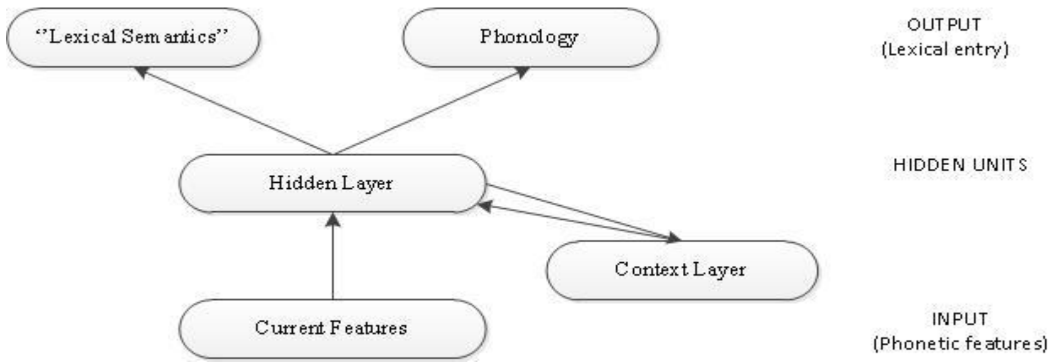

Figure 8: Overview of the distributed model of speech perception, from Gaskell & Marslen-Wilson, 1997, 617.)

3.2.2.1 Imageability and PND in the integrated connectionist model

Because both semantics and phonology are represented in parallel and activated simultaneously, there should be an interaction between imageability and phonological neighborhood density. As it is known that high phonological neighborhood density slows down the recognition of words, but high imageability facilitates the perception and recognition of words, the interaction between imageability and PND should be seen in the response latencies of high imageable high PND words. The high imageability should help speed up the recognition of the otherwise slow to recognize high PND words.

3.3 Research questions

In light of previous research on both imageability and phonological neighborhood density (PND) effects, and especially due to the alternately use of the terms concreteness and cohorts for imageability and PND respectively, it would be both relevant and interesting to look at how the two effects interact during language processing. When it comes to phonological neighborhood density there seems to be a consensus that a dense neighborhood will help speed up production, but slow down perception of a word. Imageability is said to have similar effects on production and perception, namely that it helps speeding up and correctly retrieving words from the mental lexicon. An overreaching goal of this thesis is to test if the Norwegian data follows this pattern too. But I also want to address certain issues in relation to imageability and phonological neighborhood density effects together.

I will test informants with word-finding difficulties (anomia) due to aphasia and a control group with no known linguistic or cognitive impairments on a set of different words. The words should come from the following four factor groups: Words with high imageability scores and dense phonological neighborhoods (HiIMG+HiPND), words with high imageability scores and narrow phonological neighborhoods (HiIMG+LoPND), words with low imageability scores and dense phonological neighborhoods (LoIMG+HiPND), and words with low imageability scores and narrow phonological neighborhoods (LoIMG+LoPND), as seen in Table 2 below. An analysis of error patterns and reaction times will hopefully be able to tell us something about the processes that are involved in lexical retrieval of single-word lexical items.

	High Imageability	**Low Imageability**
High PND	High Imageability + High PND	Low Imageability + High PND
Low PND	High Imageability + Low PND	Low Imageability + Low PND

Table 2: The four imageability/neighborhood density interaction categories for testing purposes.

Firstly I want to see if there is any difference in words of high/low imageability vs. words with high/low PND, in production as well as in perception.

In production, both imageability and PND have proven to speed up lexical access, but are they equally facilitative, or will one factor overrule the other? Is there a competition between imageability and PND during lexical access? Will words that have two facilitative factors (high imageability scores and high PND) have a double advantage compared to words with only one facilitative factor? An interesting next step will be to see what happens to the in-between word groups with one high and one low factor. Is it easier to produce a low imageable word if the phonological neighborhood density is high? Will there be a difference in naming latencies and/or error productions between the words with high imageability and low neighborhood density and the words with low imageability and high neighborhood density?

In perception, high PND has been shown to slow down recognition of a target word, but imageability has the opposite effect, and speeds up recognition. Will a word's PND be so defining for the lexical access that it will slow down the perception of high imageability words? Or will imageability affect the lexical access in such a way that the otherwise difficult high PND words are unaffected by their own competitors?

Furthermore, I want to test and compare the effects of the two factors on normal and language impaired speakers, to see if there are any significant differences that might give us a clue to which processes that might affect lexical access. The informants from the normal control group will also be compared within the group to see if there are any differences, especially with regard to age. In the imageability study by Simonsen et al. (In print), one main finding was that there was a significant difference in imageability rating between subjects over and under 50 years of age. Because my material is based on the material from Simonsen et al. (In press), I would expect to see a similar pattern in the results from this study.

One major prediction concerning production is that the words with both high imageability scores and high neighborhood density will be retrieved faster and with greater accuracy than the words with low imageability scores and low neighborhood density.

I suspect that the high imageable words with few neighbors will be recognized faster and more accurately than low imageable words with many neighbors, because the more neighbors a word has, the more it competes with other, similar-sounding words in perception. Another prediction I want to test is if imageability will overrule neighborhood density in such a way that high imageable words, regardless of the neighborhood density, will be recognized faster and with fewer mistakes (i.e. mistaking a real word for a non-word) than low imageable words. This leaves a response time and accuracy hierarchy for perception with high imageable words from narrow neighborhoods (HiIMG+LoPND) on top, followed by high imageable words from dense neighborhoods (HiIMG+HiPND) before low imageable words from sparse neighborhoods (LoIMG+LoPND), and low imageable words from dense neighborhoods (LoIMG+HiPND) as the predicted slowest word group, an overview of the predicted reaction time hierarchy can be seen in Figure 9 below.

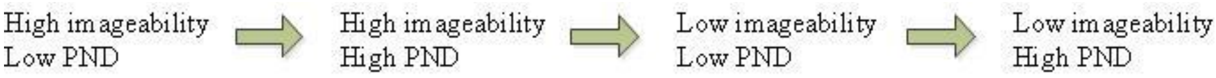

Figure 9: Predicted RT hierarchy for perception.

In production, high imageable words with high PND should be retrieved and named faster and more accurately than high imageability words with low PND, which again should be faster and more accurately produced than low imageable words with high PND, and as the slowest and least accurate word group I would predict the low imageable words with low PND. How the results match the predictions is discussed in chapter 5.1.

4 Data collection and methodology

This chapter focuses on the methodology used for generating a testable word list, and the further data collection which serves as a basis for the results and discussion in chapter 5 and 6. First I outline how the words were selected, and then I move on to discuss why it is of interest to researchers working with speech processing to study the speech of persons with acquired language deficits. Finally I describe how the tests in this study were conducted.

4.1 Word selection

As the object of this study is to test how imageability and phonological neighborhood density interact during language processing, in perception as well as production, I had to create a set of words suitable for testing. The words had to fit into one of four categories: highly imageable words from dense phonological neighborhoods (HiIMG+HiPND), highly imageable words from sparse phonological neighborhoods (HiIMG+LoPND), low imageable words from dense phonological neighborhoods (LoIMG+HiPND) and low imageable words from sparse neighborhoods (LoIMG+LoPND). Furthermore, the words had to be matched in frequency of use and number of syllables to make sure that those factors would not influence the results in any way.

To build this word list I used three different tools (NOWAC, NORKOMPLEKS and LINGUA, see point 4.1.2 below) to extract information about neighborhood density from a set of 1600 (897 nouns, 483 verbs and 220 adjectives) Norwegian words with imageability ratings. The imageability ratings were obtained in a study run by the Research group in clinical linguistics and language acquisition at the University of Oslo (Simonsen, Lind, Hansen, Holm, Mevik. In press). As there were no previous neighborhood density data available for Norwegian I had to calculate this myself with assistance from the Text Laboratory at the University of Oslo.

For the purpose of this study I have disregarded verbs and adjectives, and only focused on nouns as imageability effects are more pronounced for nouns than for other word classes (Bird et al., 2001, McDonough et al., 2011). By limiting my material to one word class only, I can make sure that part of speech does not influence the results in any way (Schmitt, 2010, 160). Further, there is no reason to expect that phonological neighborhood effects will affect one word class more than another. Phonological similarity among words can be found within and across word classes, as seen for the Norwegian noun *katt*, which has the adjective *matt* ‘matte’, the conjunction *at* ‘that’, and the verb form *kan* (the present tense of the verb *kunne* ‘can’) among its neighbors. I also decided to disregard all compounds, as it is statistically more difficult to find words that differ in one sound only when the words are longer and more complex.

Words are regarded as highly imageable if they obtain a score of five or higher on a seven point scale, where 1 means that the word does not give rise to a mental image, and 7 indicates that the word is highly imageable. A dense neighborhood in this case means 14 or more phonological neighbors. Low imageable words have an imageability score of four or lower on the same seven point scale, and a sparse neighborhood consists of 11 or fewer neighbors. The average number of phonological neighbors for the low PND words is 3.77 (standard deviation 3.44) neighbors, and the average number of neighbors for high PND words is 20.12 (standard deviation 6.18) neighbors. The borders for what is regarded as low or high imageability and phonological neighborhood density were drawn after phonological neighbors had been calculated for all words in the imageability material. The differences between high and low phonological neighborhood density is quite small, but the material did not allow for a larger gap between high and low PND, or I would not find enough words for the low imageability low PND word group to carry out the tests. The mean number of neighbors for all the nouns was 11.7 (standard deviation 9.58) and the average imageability score for all the nouns was 5.03 (standard deviation 1.30). How imageability and phonological neighborhood density was obtained is discussed in the two following chapters, 4.1.1 and 4.1.2 respectively.

4.1.1 Imageability scores

The imageability data were collected by the Research group in clinical linguistics and language acquisition at the University of Oslo between 2011 and 2012 (Simonsen et al., In press). I based my word selection on the final material from April 2012, consisting of 1600 words with imageability ratings, frequency counts and age-of-acquisition data. Of the 1600 words, there were 897 nouns, 483 verbs and 220 adjectives. Imageability ratings were collected from 399 informants (153 males and 246 females)[5] who filled in an on-line survey, rating the imageability of nouns, verbs and adjectives on a seven point scale. The informants

[5] There is no absolute number of people who received the link to the study; only the number of informants who chose to reply to it has been logged.

were monolingual, native speakers of Norwegian between 18 and 75 years of age. Each informant was asked to rate 100 words, giving them a score between 1, meaning the word did not give rise to a mental image at all, and 7, indicating a strong mental image. The alternatives “ambiguous” and “unknown” were also available; only one answer per word per participant was possible. This means that it was not possible for the informants to rate the word's imageability and at the same time judge the word as ambiguous (Simonsen et al., In press).

The words used in the study were chosen from different assessment batteries for language acquisition and disorders available for Norwegian, such as MacArthur-Bates Communicative Development Inventory (Kristoffersen and Simonsen, 2012), The Verb and Sentence Test (Bastiaanse et al., 2006), Psycholinguistic Assessments of Language Processing in Aphasia (Kay et al., 2009), as well as semi-spontaneous test materials from short narrative elicitation tasks for adults, and words agreed upon for assessment tasks of an ongoing study of specific language impairments in bilingual children (COST Action BiSLI ISO804) (Simonsen et al., In press).

4.1.2 Finding neighbors in NoWaC, NorKompLeks and Lingua

As there were no phonological neighborhood data available for Norwegian when I started this work, I had to develop the data myself. With help from the Text Laboratory at the University of Oslo,[6] I created a list of roughly 20 000 000 words, based on a random selection of words from the NOWAC corpus (Guevara, 2010) – a large web-based corpus of written Norwegian Bokmål, and calculated orthographic neighbors for those words using the free neighborhood generator software LINGUA available on-line from the University of Alberta.[7] All further work on phonological neighborhoods in Norwegian for this project is based on these data.

The NoWaC corpus was created by crawling and downloading Internet documents containing the .no Internet top-level domain between 2009 and 2010. Originally, the developers intended to build a 1.5 – 2 billion word corpus, but because of the relatively limited presence of Norwegian (Bokmål) on the Internet, the current version of NOWAC “only” contains around 700 000 000 words (Guevara, 2010).

Because NOWAC is based on writings on the Internet, we may expect some sources of errors. The developers found that a great portion of the documents in Bokmål were

[6] http://www.hf.uio.no/iln/english/about/organization/text-laboratory/

[7] http://www.psych.ualberta.ca/~westburylab/downloads/lingua.download.html

probably computer generated, and not produced by human speakers (Guevara, 2010, 5). Further, it is reasonable to believe that the Norwegian Internet is at least bilingual (between Bokmål and Nynorsk) due to the linguistic complexity in Norway with two written standards, and that even other languages are present to a greater of lesser extent, i.e. Swedish, Danish, and English (Guevara, 2010, 4). It is also important to be on the lookout for regular spelling and language errors when using a web-based corpus. The Internet offers easy publishing options for all users, which makes it difficult to control the quality of all published material, even for a language with restricted on-line presence, like Norwegian Bokmål. For instance, some of the orthographic neighbors calculated by the LINGUA program (below) were in fact misspellings of quite common words.[8]

LINGUA is short for the Language Independent Neighborhood Generator of the University of Alberta, and just like NOWAC, LINGUA is also freely available on the Internet, provided that the user fills in a short form so the developers can keep track of who uses the program. The program is developed to create frequency dictionaries, calculate orthographic neighborhood densities and n-gram counts, and to generate plausible non-words in written languages based on larger corpora (Westbury et al., 2007). As the name suggests, the program is developed to be language-independent, which in theory means that it accepts input from most languages, and generates its data depending on the language in the input corpus.

The program can only calculate orthographic neighbors, afterwards the words had to be transcribed and checked manually to make sure that they were not only orthographic, but also phonological neighbors. Norwegian Bokmål and the Urban East Norwegian (UEN) dialect (see point 4.1.3), which serve as the phonological standard for the selection of words for this study, share a close orthography-to-phonology mapping. This makes the orthographic neighbors calculated by LINGUA a good place to start when calculating phonological neighbors, compared to a similar approach in languages with less orthophonic spelling, for instance English or French. Still other languages, like Finnish or Turkish, would show a closer match between orthographic and phonological neighbors, and it would probably be even easier to generate phonological neighbors based on orthographic neighbors in such languages.

[8] For the word *absolutt* (absolutely) LINGUA found one neighbor in the NOWAC material, namely *abselutt*, which is nothing more than a misspelling.

Although LINGUA is a good tool for creating neighbors, it has some limitations. The program is for instance not able to run large corpora, like the whole NOWAC corpus, and although 20 000 000 words sounds like a lot; it is apparently not enough for a thorough calculation of neighbors in Norwegian. Because of the restricted input material, LINGUA only calculated three neighbors for the word *bygg /*[1]*byg/* '(a) building' (Table 3), but as a native speaker it is not difficult to come up with at least three more, and still we have not covered all possible neighbors for the noun *bygg*. This example shows us that there is still much work to be done before we have a fully satisfactory overview of Norwegian nouns and their phonological neighbors.

Target word	No. Neighbors			
BYGG	3	RYGG	MYGG	BYGD

Table 3: Raw selection from the LINGUA file for the noun bygg /[1]byg/ 'a building' and its orthographic neighbors

The use of LINGUA on the NoWaC corpus was only the first step towards finding phonological neighbors to the words from the imageability data. To supplement the existing material, I was granted access to the NorKompLeks lexicon, a computational lexicon for Norwegian Bokmål and Nynorsk, from the Norwegian University of Science and Technology.[9] Because I base my word selection on the Urban East Norwegian (UEN, see below) pronunciation of Norwegian, the Bokmål version of the lexicon was all I needed. The lexicon is a transcribed version of Bokmålsordboka,[10] with information about pronunciation as well as information about the words' grammatical properties. This material is transcribed in the ASCII-based phonetic alphabet SAMPA, which LINGUA cannot read. Still, the transcribed material in NorKompLeks gives us a good starting point when determining phonological neighbors.

One major difficulty with NorKompLeks is that some sounds, like the UEN retroflex sounds, are transcribed as sequences, as they are in standard Norwegian orthography. This means that the sounds /ʈ,ɖ/ are transcribed as [rt] and [rd] in NorKompLeks. In theory this means that transcribed words containing one of these sequences could potentially represent a

[9] http://www.clarin.eu/norkompleks A computational lexicon for Norwegian, developed by the Norwegian University for Science and Technology and Telenor.
[10] A dictionary for the Norwegian written standard *Bokmål* with approximately 65000 tokens. http://www.nob-ordbok.uio.no

consonant cluster, as in *myrde* /myɾde/ ‘to murder’, or the retroflex sounds, as in *myrte* /myʈe/ ‘myrtus’. This poses a problem when trying to substitute one retroflex sound in NorKompLeks with another sound to find neighbors, because the sounds sometimes get substituted by one segment, and sometimes by two.

Firstly, the lexicon was converted to IPA, to make the systematic substitution of phonemes more efficient. The University of Oslo’s Text Laboratory created a program similar to LINGUA that could extract phonological neighbors from the NorKompLeks lexicon. Each noun from the imageability study was then run through this program which calculated phonological neighbors for each word based on the phonologically transcribed entries from Bokmålsordboka. Table 4 shows the number of neighbors calculated for *bygg /^{1}byg/* ‘a building’ in NorKompLeks, which is a lot more extensive than the three neighbors initially found in LINGUA.

Target word	PND					
Bygg	15	rygg	mygg	bag	tygg	bygd
/^{1}byg/		/^{1}ryg/	/^{1}myg/	/^{1}bæg/	/^{1}tyg/	/^{1}bygd/
		byll	skygg	brygg	bydd	bygget
		/^{1}byl/	/^{1}ʃyg/	/^{1}bryg/	/^{1}byd/	/^{1}bygə/
		bygga	byrg	byss	bytt	hygg
		/^{1}bygɑ/	/^{1}byrg/	/^{1}bys/	/^{1}byt/	/^{1}hyg/

Table 4: Final version of bygg /^{1}byg/ ‘building’ with its 15 neighbors extracted from the NorKompLeks lexicon.

The nouns were left in their citation form, which for Norwegian means the indefinite singular form (i.e. *bygg* /^{1}byg/ - ‘(a) building’). I then matched the LINGUA generated word list with orthographic neighbors to the word list with imageability ratings. Of the original 897 nouns from the imageability material, 622 were also found in the LINGUA/NOWAC file with orthographic neighbors. These were again checked manually to weed out errors, including, but not limited to, orthographic neighbors that are not also phonological neighbors, misspellings, non-words, abbreviations and words from other languages than Norwegian. Only words that can be found in the on-line version of *Bokmålsordboka* were accepted. The lowest possible number of phonological neighbors is 0, and the highest I found is for *rake* /^{2}rɑːke/ ‘rake’ with 38 neighbors. These numbers give us a good indication of how many phonological neighbors these Norwegian nouns have, but they are not absolute numbers; a word might have even more neighbors that for some reason are not listed in *Bokmålsordboka*.

4.1.3 When are words neighbors?

As mentioned above, there are no previous data on phonological neighborhoods in Norwegian, which meant that I had to decide on the criteria myself. The definition of phonological neighborhood as presented by Luce and Pisoni (1998, 3) is a collection of words that are phonologically similar to a given stimulus word. The words in the neighborhood differ from the target word in only one sound, at any place in the words, with the remaining phonemes in the same position in the target word as in the neighbors. If we look at the aforementioned example *katt*, and two of its neighbors *skatt* /^{1}skɑt/ ‘treasure’ and *at* /^{1}ɑt/ ‘that’, and align the words at the vowel we see that the words share all phonemes but one, and the shared phonemes are all in the same positions. This means that two words may share the same neighbor without being each other's neighbors, as seen in Figure 10 below where both *skatt* and *at* are neighbors of *katt* without being each other’s neighbors.

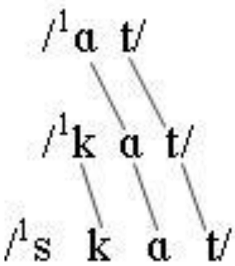

Figure 10: Katt /^{1}kɑt/ with the neighbors /^{1}skɑt/ and /^{1}ɑt/.

A first problem concerning which words are phonological neighbors in Norwegian was to define what we understand by Norwegian. Because the language does not have an official spoken standard, and all dialects are, in theory, regarded as equal, I could have chosen any spoken variety I liked. For the sake of simplicity I decided to base my word selection on the system described by Kristoffersen (2000) for Urban East Norwegian (UEN), this is not only the best described variety of Norwegian, but it is also the variety used by approximately half of the speakers of Norwegian.[11]

A second problem I encountered concerned tonal distinction. Most Norwegian dialects, including UEN, distinguish between two contrasting tonal accents, often dubbed *toneme 1* and *toneme 2* (Kristoffersen, 2000, 233). In transcription, toneme 1 and 2 are marked by a superscript 1 and 2 respectively. Because some words in Norwegian can be distinguished by tone alone I have accepted minimal pairs that differ solely by tone to be neighbors, but if two words differ in tone in addition to a phoneme, they are too distinct to be regarded as neighbors. In this view *målet* /^{1}moːle / ‘the goal’ and *måle* /^{2}moːle / ‘to measure’ are neighbors, but *målet* /^{1}moːle/ ‘the goal’ and *male* /^{2}mɑːle/ ‘to paint’ are not.

A third restriction concerned vowel length. As with tonal distinctions, vowel length can potentially distinguish between words in Norwegian, and the same restriction as with tonal differences was applied to words with contrasting vowel length; minimal pairs that differ in vowel length alone are regarded as phonological neighbors, but words that differ in vowel length and a phoneme or tone, are not. This means that the noun *juice* /^{1}jʉːs/ has, amongst others, the neighbors *juss* / ^{1}jʉs/ ‘jurisprudence’, and *hus* /^{1}hʉːs/ ‘house’, as well as *bus* /^{1}bʉːs/ ‘miner’, but not *buss* /^{1}bʉs/ ‘bus’. In the same manner, *båre* /^{2}boːɾe/ ‘stretcher’ and *borre* /^{2}boɾe/ ‘to drill’ are neighbors, but not *båre* /^{2}boːɾe/ ‘stretcher’ and *borret* /^{1}boɾe/ ‘the drill’.

Although the words I am concerned with in this selection are nouns in their citation form, the neighbors may come from any word class and inflection form. All forms I have accepted as neighbors to a given target word are found in the on-line edition of *Bokmålsordboka*.

4.1.4 The words

For testing purposes I needed 92 words, chosen from the abovementioned list of 897 nouns from the imageability study by Simonsen et al. (In press). LINGUA found 622 of those nouns in NoWaC. These 622 nouns served as my starting point for further narrowing down the sample of nouns.

By factoring out frequency, part of speech and number of syllables I could reduce the chance of these factors influencing the test results in any way. There may still be factors that

[11] Based on numbers from Statistics Norway: http://www.ssb.no/emner/02/02/folkendrkv/2012k2/kvart00.html

can influence the results, which if found, will be dealt with below with the rest of the results. Word frequency has long been known to affect the speed and accuracy of a word's retrieval from the mental lexicon. Frequencies were found using the frequency count function in NoWaC. High- and low-frequent words were omitted from the study, and only words of medium frequency were used. The words were first sorted by imageability score and neighborhood density, creating four groups (high imageability + high PND, high imageability + low PND, low imageability + high PND and low imageability + low PND), and next by number of syllables.

This classification showed that testing disyllabic nouns would be the most appropriate. In the group of monosyllabic words the phonological neighborhood density was generally high (on average there were 17 neighbors per word, against 11.7 which was the average number of neighbors for all words taken together), whereas the groups of words consisting of three or four syllables had rather low phonological neighborhood density (on average there were 1.2 neighbors for words with tree syllables, and 1.4 for words with four syllables). Another noteworthy finding was an unexpected correspondence between word length and imageability. The words with three or four syllables had lower than average imageability scores compared to the words with one or two syllables. Four syllable words had an average imageability score of 3.6, whilst the three syllable words scored somewhat higher, but still generally low, with an average of 4.6 on a seven-point scale (average imageability score for all 622 nouns was 5.2). A final argument for not choosing longer than two-syllable words was also mediated by my wish not to make either of the tasks too difficult for the informants with aphasia.

The disyllabic words were evenly spread out along the specter with regard to both imageability and neighborhood density, which made it easier to choose testable words from this group. The words can be seen in appendices I and II for lexical decision and picture naming respectively. I first made a choice of 23 words from the low imageability/high neighborhood density group, as this was the smallest group, and further modeled my choice of words from the other groups on the nouns chosen in the first group. As far as possible I tried to exclude nouns that could also be verbs, so that I could try to keep the material to one word class only. In the low imageability and high neighborhood density group, only 27 nouns met the requirements of two syllables and medium frequency. As 23 of these nouns were needed for testing, it was not possible to unconditionally exclude nouns that could also be verbs from the low imageability, high PND category. So, by restricting my selection to disyllabic nouns with more or less medium frequency, I found the most suitable nouns for testing.

4.2 Linguistic aphasiology

Aphasia is a language disorder following an acquired, focal brain injury, often caused by a stroke, or some other conditions that can affect the brain, like tumors and other traumas. There are many types and forms of aphasia, and patients may show a great deal of individual variation. All aphasic patients have in common that they have suffered some kind of brain damage which has damaged neuronal cells in parts of the brain on which language seems to be critically dependent (Lesser and Milroy, 1993).

Studies of patients with acquired language disorders, like aphasia, are often used to attest the relationship between language and the brain. One of the goals in linguistic aphasiology has been to increase the insight into normal linguistic processes through studying the deviations observed in patients suffering from a brain injury (Moen, 1995). An injury in one part of the brain can affect different functions of the language, and linguistic aphasiology tries to explain the linguistic behavior in persons with said injury by comparing it to normal language processes. One benefit of linguistic aphasiology is that one can make quite strong claims about normal language representation and processing when comparing speech from speakers with acquired language impairment to the typical language use of neurologically healthy speakers.

There is reason to believe that as long as there has been speech there has also been aphasia and other kinds of speech impairments. Some of the first attested occurrences of speech and language problems are found in the Egyptian physician and politician Imhotep's writings (approximately 400 BC), where at least one case exhibits signs of traumatic aphasia (Tesak and Code, 2008). Still, it is not possible to talk about aphasiology as a science until at least the 19th century when the serious and systematic study of aphasia began. The breakthrough came with Paul Broca who in 1861 described a patient's speech disorder, supporting it with anatomical evidence, suggesting that control of articulate speech is localized in the inferior frontal cortex, now known as the Broca's area (Tesak and Code, 2008, 49). Aphasiology as we know it today originates with Roman Jacobson's work on aphasia from the early 1940s, and grew in the aftermath of Noam Chomsky's transformational grammar from the late 1950's (Tesak and Code, 2008, 179).

As it is difficult to get inside the brain when studying language processing, we need to rely on external evidence to study the relationship between language and the brain. This evidence can come from many different sources, for instance studies from different types of atypical language use. Deviant language can serve as a “window” into how the non-deviant language system is organized by looking at the relationship between the language defect and the cognitive operations necessary for normal language perception and production (Lind, 1995). To be able to do this, one has to assume that there are certain cognitive structures, or special areas of the brain, that are specifically linked to production and perception.

The study of the relationship between language and the brain relies to a great extent on the study of abnormal language use, and throughout history aphasia has been an important source of information for this relationship. Since the beginning of the history of psycholinguistics, researchers have studied atypical populations and informants with different brain deficits, and have later made use of neural imaging, invasive studies of patients undergoing brain surgery, and elicitation tests to get insight to the neural substrates of naming and perception (Bergen, 2007).

4.2.1 Types of aphasia

Although aphasia manifests itself in patients who have suffered some kind of focal trauma to the language dependent areas of the brain, it is not one single symptom. Aphasia may take different forms depending on the underlying injury, and the individual symptoms can be so different that it is convenient to talk about subclasses of aphasia, or different aphasia syndromes. There are different traditions as to how aphasia syndromes are classified.

One central classification is based on neurological and anatomical assumptions of specific language areas in the brain (Reinvang and Engvik, 1980). Damage to one specific area will lead to certain difficulties, and damages to other parts of the brain will result in other deficits. Table 5 (adapted from Obler & Gjerlow, 1999) gives a schematic overview of the classifications of the syndromes and the related brain areas according to this tradition.

Syndrome	Speech	Comprehension	Repetition	Naming	Lesion site
Broca's Aphasia	Poor, non-fluent	Good	Poor	Poor	Anterior
Wernicke's Aphasia	Fluent, empty	Poor	Poor	Poor	Posterior
Conduction Aphasia	Fluent	Good	Poor	Poor	Arcuate fasciculus
Anomic Aphasia	Fluent with circumlocutions	Good	Good	Poor	Anywhere
Global Aphasia	Virtually none	Poor	Poor	Poor	Large
Transcortical Motor Aphasia	Little	Good	Good	Not bad	Outside in frontal lobe
Transcortical Sensory Aphasia	Fluent	Poor	Good	Poor	Outside in parietal lobe

Table 5: Overview of aphasia types with syndromes, from (Obler and Gjerlow, 1999, 40)

Another classification can be made based on the output speech from speakers with aphasia. Despite the many individual differences, one can isolate two main patterns of aphasia, one fluent and one non-fluent form. These main types are often used as a basis for an even finer categorization, and we can distinguish three different patterns of impairments in language: a non-fluent pattern, a fluent, but deviant pattern, and another fluent, but less deviant pattern of speech. The different patterns of speech impairments are a mixture of symptom complexes; these are not specific to aphasia alone, but can also be observed in other clinical populations. One main symptom that is present in all forms of aphasia documented, is anomia, or word finding difficulties (Bates and Goodman, 1997).

In the non-fluent pattern one can observe both grammatical and lexical deficits. Grammatical deficits are characterized by omission of function words, and lexical deficits are usually observed as a reduction of the number of content words and frequent word finding difficulties. This symptom complex is often also associated with Down's syndrome (DS) and some cases of Specific Language Impairment (SLI), in addition to Broca's Aphasia (BA) (Bates and Goodman, 1997).

The fluent and deviant pattern is characterized by substitution of inflections, function words and content words, and often by semantic and/or phonological paraphasias. This pattern is mainly found in Wernicke's Aphasia (WA), and to a lesser extent in patients with Williams Syndrome (WS).

The last pattern is often described as fluent and less deviant and is also observed in early stages of Alzheimer's Disease (AD), some forms of anomic aphasia, and to some extent, in elderly speakers without any language impairment. It is characterized by simplification and avoidance of complex syntactic structures, excessive use of pronouns and relatively empty lexical forms (Bates and Goodman, 1997). Although these symptoms may resemble the symptoms in other clinical groups, like DS, SLI, WS and AD mentioned above, aphasia is not a syndrome or a disease like the aforementioned conditions, but a result of damage to the parts of the brain where language is assumed to play a central role.

4.3 Testing

Participants from two different groups were tested on two different tasks: Picture naming and lexical decision. The picture naming task was designed to measure the interactions of neighborhood density and imageability in production, whereas the lexical decision task tested the same factors in perception. The first group consisted of 3 speakers with aphasia, and the second group consisted of 30 control subjects with no known cognitive or linguistic disorders, 15 of them were under 50 years old, and 15 aged 50 and older. The goal of the tests was not only to map the differences between the two groups, but also to see if there were any in-group differences within the control group. Both tests were developed using the ACTUATE testing software available from Westbury Lab at the University of Alberta (Westbury, 2007).[12]

The ACTUATE program is designed to be a simple, user friendly alternative to commercial experiment environments and programs, without being a full replacement for such programs (Westbury, 2007). The program can present sound, video, images, audio and text file stimuli and time responses to these with millisecond accuracy, or record spoken responses if needed. ACTUATE is a free software released under creative commons, which means that it can be downloaded and used for many non-commercial purposes, including

[12] http://www.psych.ualberta.ca/~westburylab/downloads/actuate.download.html

instructional exercises, simple testing or even for patients for self-assessment on their home computers (Westbury, 2007, 3). Another advantage of using ACTUATE is that it can easily store responses from multiple experiments by one or more subjects, which makes it easy to compare one informant with another, as well as to compare the same informant's results on different tests or subtests.

4.3.1 Participants

Two informant groups participated in the study. The first group consisted of three males who had suffered a brain trauma that left them with aphasia; the second group consisted of 30 neurologically healthy control subjects. All informants were native speakers of Norwegian.

The control group was again divided in two; half of the participants were under 50 years old, and the other half were aged 50 and older. The main reason for dividing the group like this was based on a finding from the study on imageability ratings for Norwegian, where age proved to be an important factor (Simonsen et al., In press). The participants for this study were recruited via personal networks, and e-mails were sent out to first year students of Scandinavian studies at the University of Oslo and faculty members at the Faculty for Technology, Art and Design at the Oslo and Akershus University College of Applied Sciences. The mean age for all 30 control informants was 43.2 years. The mean age for the 15 oldest informants was 59.2 years, and the 15 youngest had a mean age of 27.3 years. 15 men and 15 women participated in the study, but there were more men in the older group (9 males and 6 females) and more women amongst the youngest participants (9 females and 6 males). An overview of the participants by age group can be seen in Tables 6 and 7.

Age	27	25	25	23	28	24	34	21	32	38	28	25	23	21	26
Gender	M	F	F	F	M	F	M	M	F	F	F	M	F	F	M

Table 6: Overview of age and gender of the younger informants in the control group (M = male, F = female).

Age	60	72	56	54	56	53	54	55	56	56	69	62	60	57	62
Gender	F	F	M	F	M	F	M	M	M	F	M	M	F	M	M

Table 7: Overview of age and gender of the older informants in the control group (M = male, F = female).

The group of aphasic informants was recruited through speech therapists at Bredtvet Resource Center in Oslo, where the testing of this group was also carried out. Informant 1 (henceforth I1), a 65 year old male, had suffered a stroke seven years earlier. According to "The Norwegian Basic Aphasia Assessment" (Reinvang and Engvik, 1980), his aphasia is more of a non-fluent type aphasia, in as much as his production is sometimes effortful and slow.

The second informant (I2) had also become aphasic due to a stroke, 4.5 years earlier. He was 77 years old when tested. As with I1, his speech is not fast enough to be characterized as fluent, with less than 80 words per minute (Reinvang and Engvik, 1995, 47). He was generally slow in the visual-auditory lexical decision, and said that he "needed to see if the letters made sense in that position" to make out if what he saw was a real word or a non-word.

The third informant (I3) was a 46 year old male. He had suffered from aphasia due to a stroke three years earlier. As the two others, his speech was slow and effortful, and he also showed great motoric difficulties due to speech apraxia. In an informal self-evaluation after the test he said that he "has the words in the mind, but not in the mouth".

4.3.2 Auditory and visual lexical decision

The lexical decision test was similar for both groups. The participants were tested on 32 real words and 32 non-words. The words were matched in frequency and number of syllables, and fitted into one of four categories depending on their imageability and phonological neighborhood status: high imageability + high PND, high imageability + low PND, low imageability + high PND, or low imageability + low PND (see appendix I), giving eight real words from each category. The non-words were selected from the auditory processing testing material of the Norwegian edition of the Psycholinguistic Assessments of Language Processing in Aphasia (PALPA) (Kay et al., 2009). The non-words were chosen to match the real words in number of syllables.

During testing each word was presented, both visually and aurally on a computer screen, one at the time in a random order. The program's "randomize" function makes sure that the words are always presented in a new order for each participant, and never twice in the same order. The words were preceded by a cross bar (+) 750 milliseconds before stimulus onset to prepare the participants for the next word. The informants were asked to press one key if the letter string they saw and heard was a real word in Norwegian, and another key if the stimulus was not a real word. The program recorded the participants' reaction time and correct and incorrect answers. All words were presented visually in a white rectangle towards a black background. Presenting the stimuli both visually and auditorially means that weak readers are not excluded as informants, this is particularly important for the informants with aphasia. All words for the auditory presentation were recorded by a professional voice actor.

As outlined in chapter 3.3, based on what is known from previous research, the following predictions can be made about the reaction times for the words in this task:

- Highly imageable words will be recognized faster and more accurately than words with low imageability scores.
- Words with few neighbors will be recognized faster than words with many phonological neighbors.
- If there is an interaction between imageability and phonological neighborhood density in perception there will be a significant difference in how fast high imageability words from sparse neighborhoods are recognized compared to low imageable words from dense neighborhoods.

We can postulate a “reaction time hierarchy” for the four word categories; High imageability + low phonological neighborhood density > high imageability + high phonological neighborhood density > low imageability + low phonological neighborhood density > low imageability + high phonological neighborhood density.

4.3.3 Picture naming

The second test was designed to test interactions between imageability and phonological neighborhood density in naming. This test was slightly different for the two groups of participants. The control group was asked to name a picture presented on a computer screen, while simultaneously completing a non-linguistic task, solving simple calculations, as a distractor. The ACTUATE testing program recorded the answers with reaction times. All recordings were later analyzed and checked for errors. The speakers with aphasia were given the same test, but without the distractor task.

The target words were 60 nouns matched in length and frequency, stemming from either of four categories (see appendix II). The pictures were colored, cartoon-like drawings downloaded from the picture database clipart.com, and presented against a white background. Some examples can be seen in appendix III. Each picture was preceded by a short beeping sound 500 msec before it appeared on the screen to prepare the informant for the next picture.

All participants were given the same pictures, but as with the lexical decision task the pictures were presented in random order, and never in the same order for two subjects.

Pilot testing showed that certain items were more difficult to name than others, irrespective of the imageability scores and/or phonological neighborhood density. These are especially words with a more high-frequent synonym, or near-synonyms, like *unge* /²uŋe/ 'kid', for which the synonym *barn* /¹bɑːɳ/ 'child', might be just as good an answer. Words such as *vante* /²vɑnte/ and *hanske* /²hɑnske/ may also be difficult. Both can be translated into English as 'glove', but the first is usually knitted, or made of a thinner fabric than the latter. This example may be particularly difficult because some Norwegian dialects do not distinguish between the two; one informant even reported that in her dialect the word *votter* 'mittens' are used for all garments that keep your hands warm. In these cases all words might be activated to an equal level. These words are discussed in depth later with the rest of the results.

4.3.4 Reaction times

Reaction time (RT) refers to the total amount of time between exposing a sensory stimulus to a participant and the participant's response. Because reaction time tests can measure both how one subject responds to different stimuli, and how different participants react to the same stimulus, RT has been a favorite experimental method for psychologists since the middle of the 19^{th} century (Kosinski, 2010). Reaction times results may tell us something about what kind of stimuli most quickly grab the participants' attention, and which are harder to process. Testing reaction times in this study might give us a clue as to whether high imageability words from dense phonological neighborhoods have a double advantage in language processing; cf. the research questions outlined in chapter 3.3 above.

One reason why many researchers prefer reaction time testing to other elicitation experiments, or evidence from speech errors, may be that the results say something about the normal language processes. Another reason is that reaction times give us reliable data about the time course of a mental process; response latencies are often seen as a reflection of the mental accessibility of a word (Hasson and Giora, 2007, Levelt et al., 1999).

There are three kinds of reaction time experiments: Simple, recognition, and choice reaction time experiments (Kosinski, 2010, 2). In the simple RT experiment there is only one stimulus and one response, and the goal is to test how fast the participant reacts to the presented stimuli. This is the kind of reaction time experiment used for the picture naming task. The informants will see one picture at a time, and as soon as they give an answer to what they see, they will move on to the next picture. The reaction times are logged together with their oral responses.

In recognition reaction time experiments there are multiple stimuli, but only one response. In these experiments there is a difference between "the memory set", stimuli which should be responded to, and "the distractor set", which should not be responded to. This test is often called the "go/no-go test" (Trommer et al., 1991), referring to how the participants need to react ("go") when the target stimulus is presented, and not respond ("no-go") when exposed to a distractor stimulus.

Choice reaction time experiments require the participants to respond to all stimuli, and each stimulus corresponds to one answer only, such as when a participant is asked to press a key on a keyboard that corresponds to a letter if that letter appears on the screen (Kosinski, 2010). The experiments in this study are choice reaction time tests on lexical decision (LD), where the participants will be asked to press one key if the stimulus is a word they recognize, and another key if they do not recognize the word, i.e. a correct/incorrect answer to each stimulus.

Recognition of sound is faster than recognition of visual stimuli, which means that reaction times often are faster for auditory than for visual stimuli. Mean auditory RT for adults with no known cognitive impairment is said to be between 140 and 160 milliseconds (msec), while the RTs recorded for visual stimuli have an average of 180-200 msec. The intensity of the stimuli are also reported to have an effect on mean RT. Shorter RTs are associated with longer and stronger (i.e. visually or auditorally) stimulus presentation (Kosinski, 2010, 3).

Several factors other than stimulus type and intensity are known to affect the results of reaction time experiments, including, but not limited to, age, gender, whether the informant is right or left handed, practice, fatigue, fasting, alcohol and stimulant drugs, personality type and brain injury (Kosinski, 2010, 4-9).

5 Results

In this chapter the results from the two tests are presented and discussed. The aphasic informants will be discussed individually, as there was a great deal of individual variation among these three informants. The control group will be discussed as a group, but the results will also be compared within the group, to see if there are significant differences within the group, mainly with regard to age.

5.1 Visual and auditory lexical decision

The predicted response time latency hierarchy (HiIMG+LoPND → HiIMG+HiPND → LoIMG+LoPND → LoIMG+HiPND) was not met in either of the groups. The results from the aphasic group was also to a fairly high degree influenced by the individual differences observed in the informants, which means that it would not make much sense in analyzing the results from these informants as a group, instead I will examine the results for each subject individually.

5.1.1 Control group

As a group, the control informants were faster at recognizing high imageable words with high phonological neighborhood density than words with high imageability scores and low phonological neighborhood density. The most striking results here are concerned with PND. The result for high imageable words go against what was predicted, as high neighborhood density should slow down the reaction times, but as can be seen in Table 8 below. High PND words are recognized faster than low PND words when the words are highly imageable. The reaction times for high PND words are longer, however, when the imageability is low. Although not statistically significant, it does look like PND behaves as predicted for low imageable words, but not for high imageable words.

IMG+PND	RT (in msec.)
HiIMG+HiPND	1000.82
HiIMG+LoPND	1041.81
LoIMG+HiPND	1092.46
LoIMG+LoPND	1081.55

Table 8: An overview of the average reaction times for the four word groups on the auditory-visual lexical decision task based on responses from all 30 control subjects.

A two-way Analysis Of Variance (ANOVA) shows that the only statistically significant difference here is the difference in reaction times between high- and low imageable words. There is no statistical significant interaction between imageability and phonological neighborhood density, but there is a tendency towards shorter reaction times for low PND words when the imageability is low too. The longer reaction times for low imageability and high PND words are not significant. The results from the ANOVA can be seen in Table 9. All calculations were done with R 2.15.2 (R Core Team, 2012).

	F value	P value
IMG	9.354	0.002
PND	0.490	0.484
IMG:PND	1.459	0.227

Table 9: F and P values for Imageability, Phonological Neighborhood Density and the interaction between the two, from the two-way ANOVA.

The following boxplot (Figure 11) shows the distribution of reaction times (in msec.) for high and low imageable and PND words. The only significant difference is found between words of high- and low imageability.

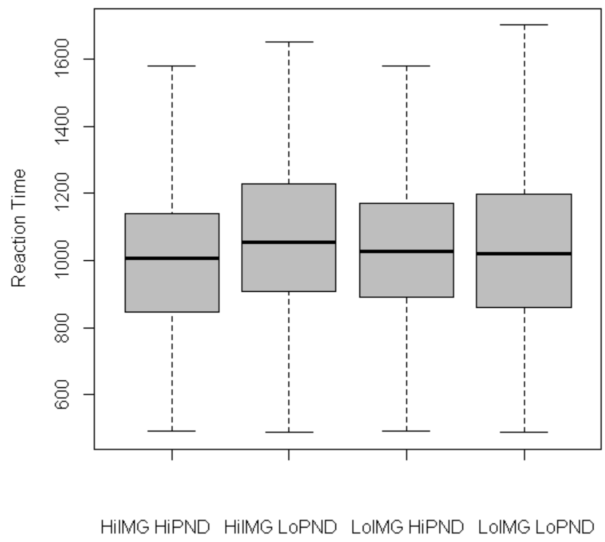

Figure 11: Distribution of reaction times for high- and low imageability and PND words for the 30 control subjects on the visual and auditory lexical decision task.

The results are fairly similar when the group is divided in two groups based on age (older and younger than 50 years of age). The younger informants had overall shorter reaction times for high imageable rather than low imageable words, and only marginally longer RTs for low imageable high PND words than low imageable low PND words, as seen in Table 10 below.

IMG+PND	RT (in msec.)
HiIMG+HiPND	1009.35
HiIMG+LoPND	1025.44
LoIMG+HiPND	1100.79
LoIMG+LoPND	1097.75

Table 10: An overview of the average reaction times for the four word groups on the auditory-visual lexical decision task based on responses from the 15 control subjects under the age of 50 years.

These results show the same tendency as was found for the whole group. A two-way ANOVA shows similar results as for the whole group together. High imageable words are recognized significantly faster than low imageable words, but there is no significant difference between high and low PND, and there is no interaction between the two factors. This can be seen in Table 11 below, and an overview of the reaction times for the four word groups by all informants are seen in Figure 12.

	F value	P value
IMG	6.189	0.013
PND	0.024	0.876
IMG:PND	0.117	0.732

Table 11: F and P values for Imageability, Phonological Neighborhood Density and the interaction between the two, from the two-way ANOVA, based on results from the 15 youngest participants.

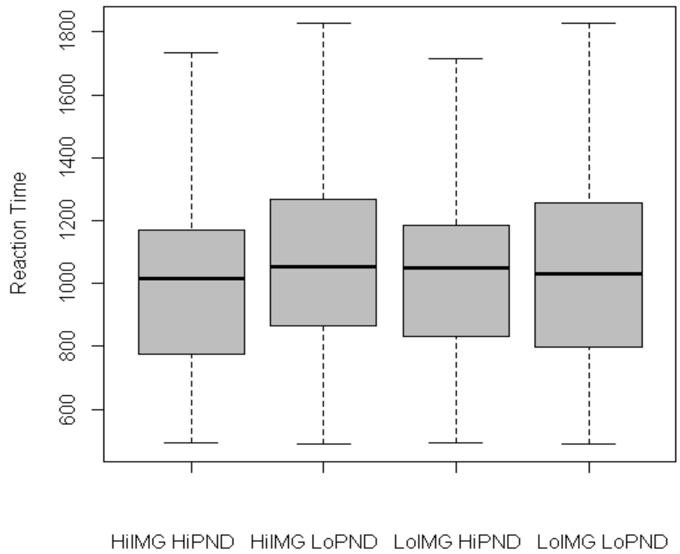

Figure 12: Boxplot that shows the distribution of reaction times for high- and low imageability and PND for subjects under 50 years of age.

This pattern repeats itself for the older participants too. High imageable words are recognized faster than low imageable words, but this is not statistically significant for this group, as is seen in Table 12 below. This could indicate that the imageability effect evens out with age. As with the younger participants, and the whole group together, there is no significant difference in the reaction times for high- and low PND words, and there is no evidence of an interaction between the two factors.

	F value	P value
IMG	3.224	0.073
PND	0.777	0.378
IMG:PND	2.068	0.151

Table 12: F and P values for Imageability, Phonological Neighborhood Density and the interaction between the two, from the two-way ANOVA, based on results from the 15 oldest participants.

The difference between high- and low imageable nouns is only a tendency, and not statistically significant, in this group (P = 0.073). The mean reaction times for the older control subjects can be seen in Table 13, and the distribution of the reaction times for this group can be seen in the boxplot (Figure 13) below.

IMG+PND	RT (in msec.)
HiIMG+HiPND	992.30
HiIMG+LoPND	1058.18
LoIMG+HiPND	1084.13
LoIMG+LoPND	1068.32

Table 13: An overview of the average reaction times for the four word groups on the auditory-visual lexical decision task based on responses from the 15 control subjects over the age of 50 years.

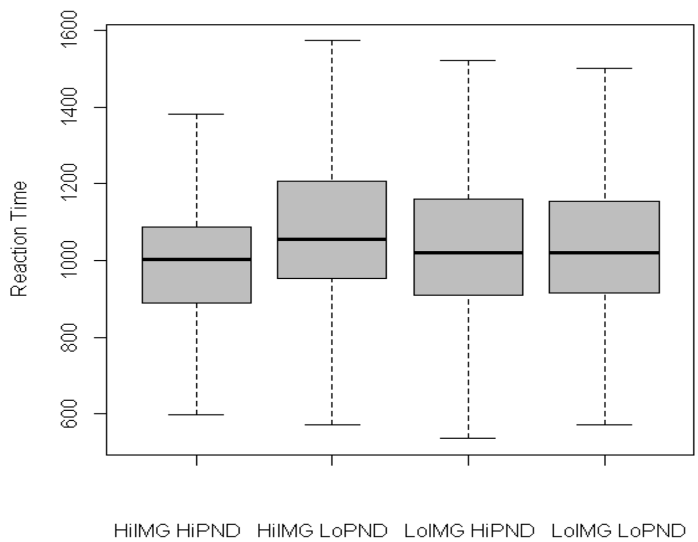

Figure 13: Distribution of reaction times on the visual and auditory lexical decision test for the control subjects aged 50 years and older.

In the imageability data from Simonsen et al. (In press), imageability ratings increase significantly and systematically with informant age, but adding age as a factor to the ANOVA in the present study does not change the results. In this material age is not significant, not by itself, or in interaction with imageability and phonological neighborhood density (cf. Table 14).

	F value	P value
Age	0.101	0.750
IMG	9.327	0.002
PND	0.488	0.484
Age:IMG	0.467	0.494
Age:PND	0.216	0.642
IMG:PND	1.455	0.227
Age:IMG:PND	0.479	0.488

Table 14: F and P values for age, imageability, phonological neighborhood density and the interaction between the three factors, from the ANOVA.

When it comes to accuracy of perception for the control subjects, three informants erroneously judged a real word as a non-word (*kjeller* 'basement', *tante* 'aunt' and *bøtte* 'bucket'), but they were all aware of their mistakes, and claimed they pressed the wrong key. Further two informants wrongly judged one non-word each (*spektes* and *simmer*), and reported they were not sure if these were real words or not. The remaining 25 informants made no mistakes in the lexical decision task.

The reaction time results suggest that in perception, imageability is a determining factor when it comes to how fast words are recognized, more so than phonological neighborhood density, at least for speakers without any known cognitive or linguistic impairment.

5.1.2 Aphasic data

A complete overview of the aphasic informants' answer to the lexical decision task with response latencies in milliseconds can be found in appendices IV to VI. I1 was the overall fastest of the three, both when it came to judging real words and non-words, closely followed by I3 and the slowest of the three was I2. Furthermore, I1 and I3 each made one mistake judging a real word as a non-word; I1 classified the low imageable, high PND word *rolle* 'a role' as a non-word, while I3 answered that the low imageable, low PND word *grøde* 'crop' was a non-word after some hesitation. I2 made four mistakes judging non-words as real words (*skete, bølde, spektes* and *kryse*).

All three informants produced substantially shorter response times for words of high imageability than for words of low imageability, regardless of the neighborhood density. They were all faster at recognizing high imageability words from dense neighborhoods rather than from sparse neighborhoods, but I1 and I2 did so only with a few milliseconds difference, whilst I3 had a somewhat bigger average difference (162 msec) between the two word groups. On the surface it looks like the phonological neighborhood density does not influence the results when the words are highly imageable, which is confirmed by an ANOVA of the reaction times for all words, excluding *grøde* 'crop', which fell outside the 95% confidence interval of the difference (see below). This shows that there are no significant factors in this group. The reaction times for each informant before the exclusion of *grøde* 'crop' can be seen in Table 15 below.

	I1	I2	I3
HiIMG+HiPND	1289	2571	1383
HiIMG+LoPND	1298	2676	1545
LoIMG+HiPND	1477	3426	1655
LoIMG+LoPND	2290	3382	1822

Table 15: Average response latencies for the aphasic informants in milliseconds before the exclusion of *grøde*.

For low imageability words, I1 and I3 showed an unexpected difference in response times for discriminating between words from dense and sparse neighborhoods when the words were of low imageability. They were faster at recognizing the low imageable words with a high PND than the low PND words, which is the opposite pattern from I2. This goes against what I predicted based on the previous research. Low imageability words with many phonological neighbors should be more ineffective in processing than low imageable words with few phonological neighbors. However, the difference in response latencies for the words with low imageability (high and low phonological neighborhood density) is not statistically significant ($t=-.696$, $p=.495$). There might be many reasons for this, including the design and small size of the dataset and individual variation between the subjects.

In the low imageability – low phonological neighborhood density group one word has been excluded from the results and discussion, *grøde,* which had an average reaction time of 7102 msec, and hence falls outside of the 95 % confidence interval of the difference. The average reaction time for all low imageability – low PND words was 2498.4 (SD 1938.4), which gives a 95 % confidence interval of the difference between 898.6 and 4098.2 milliseconds. All three informants had reaction times for *grøde* higher than 4098.2 milliseconds (I1 =9574 msec, I2 = 6918 msec, I3 = 4813 msec), and this word should therefore be disregarded.

After the exclusion of *grøde* 'crop' we now see a tendency for low imageability words from a sparse phonological neighborhood to be judged somewhat faster than low imageability words from dense phonological neighborhoods, but this is not statistically significant (cf. Table 16) This might suggest that when a word's imageability is low that same word's phonological neighborhood density can further complicate the discrimination process, which will lead to longer response latencies, and possibly errors.

	F value	P value
IMG	1.214	0.273
PND	0.307	0.580
IMG:PND	1.086	0.300

Table 16: F and P values for age, imageability, phonological neighborhood density and the interaction between the three factors for the reaction times from the informants with aphasia, after the exclusion of *grøde*.

All three informants were slowest at recognizing words from the low imageability high PND group, which might suggest that words from this group have a slight disadvantage in speech perception. Table 17 gives an overview of each informant's average reaction latencies for the different word types, excluding the word *grøde*.

	I1	I2	I3
HiIMG+HiPND	1289	2571	1383
HiIMG+LoPND	1298	2676	1545
LoIMG+HiPND	1477	3426	1655
LoIMG+LoPND	1250	2877	1395

Table 17: Average response latencies for the aphasic informants in milliseconds after the exclusion of *grøde*.

The following figures (14 -17) show a schematic representation of how fast the three informants judged the different words in each of the word groups. I1 and I3 have quite similar overall reaction times, and I2 is generally slower than the two others. In Figure 17 it is also clear that the word *grøde* was recognized a lot slower than the other words.

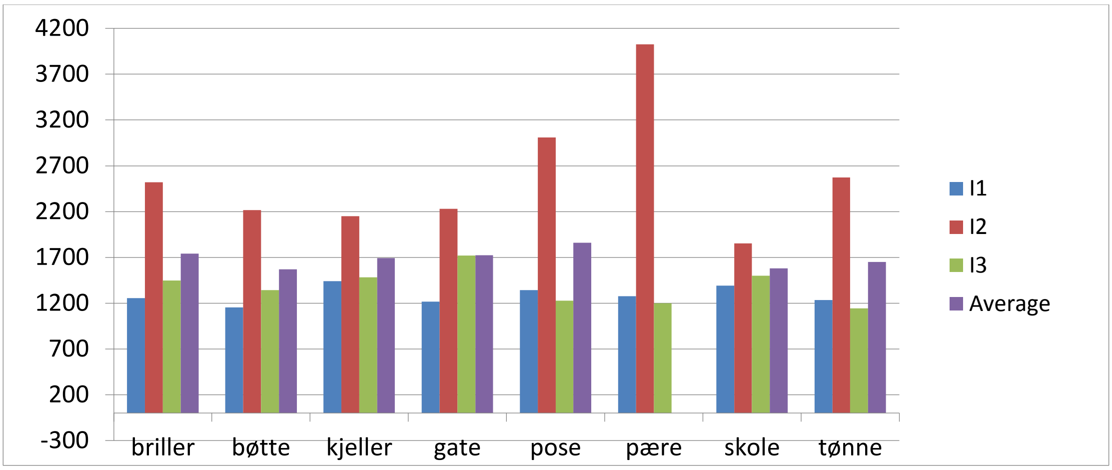

Figure 14: Reaction times (in msec) for the three aphasic informants for the high imageability high phonological neighborhood density words

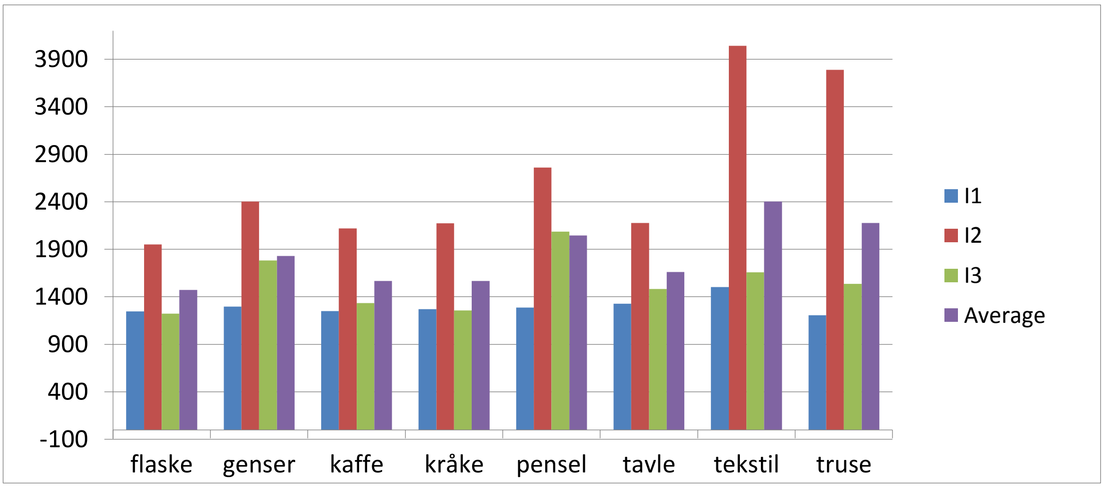

Figure 15: Reaction time (in msec.) for each of the speakers with aphasia for the high imageable low PND words.

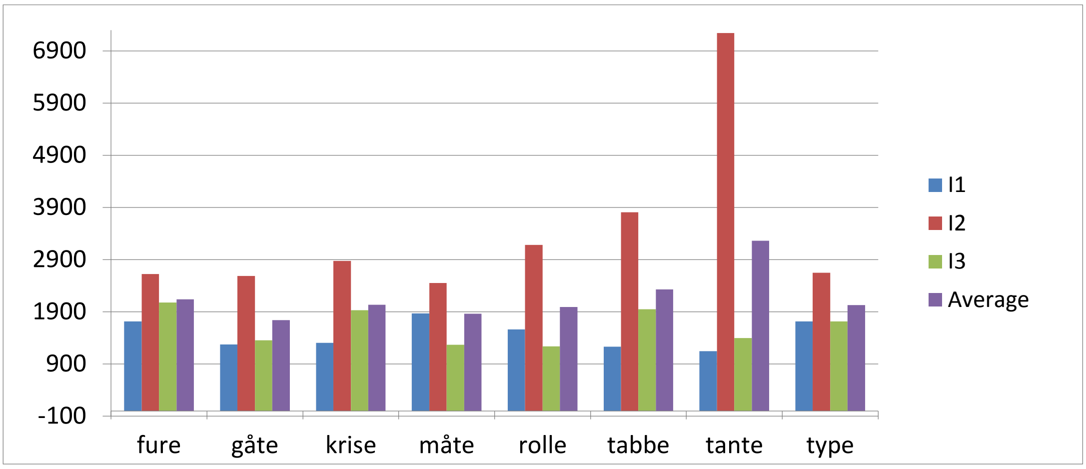

Figure 16: Reaction times (in msec) for the three informants with aphasia for the low imageability high phonological neighborhood density.

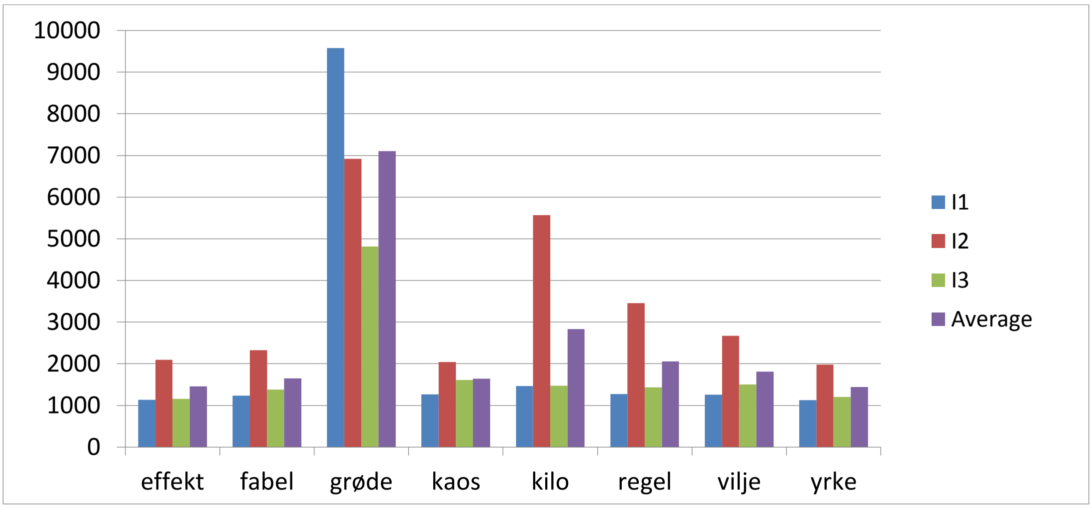

Figure 17: Reaction times (in msec.) for each informant for the low imageability, low PND words, including *grøde* 'crop'

The fact that there are no significant results for this group of speakers with aphasia might be due to the small size of the dataset, or the individual variation between the informants, and also between words within each informant, as can be seen in the figures above. As the literature suggests, words with high phonological neighborhood density should be harder to recognize than words with low PND, but as the results from these three informants show, this does not seem to be the case when the words' imageability is high. This might indicate that the facilitative effects of imageability overrule the disadvantageous phonological neighborhood density effects.

Although not significant, the reaction times from these three informants show some tendencies: Highly imageable words are recognized faster than low imageable words, and there is no effect of phonological neighborhood density. When the imageability is low, a word can benefit from a narrow phonological neighborhood if the purpose is fast and accurate recognition.

5.1.3 Summary

The above results show us that there are certain similarities between how fast the different word groups are recognized, but also similarities between the control group and the informants with aphasia in how fast words from the different word groups are recognized. Although the informants with aphasia have longer reaction times than the normal control subjects, they show the same pattern as to which word groups are recognized faster. After the exclusion of *grøde* 'crop' from the results from the informants with aphasia, the groups show exactly the same time response latency hierarchy: High imageable words with many phonological neighbors are recognized faster than high imageable words with many phonological neighbors, followed by low imageable low PND words, and as last low imageable words with high phonological neighborhood density.

The results are as predicted for imageability; high imageable words are recognized faster than low imageable words, which can be seen in the results from both informant groups. The results for phonological neighborhood density, on the other hand, are quite surprising. High PND words should, according to the literature, be recognized more slowly than low PND words, but this is not the case in these data; at least not when the target word's imageability is high.

5.2 Picture naming

With regard to production, I predicted that high imageability words with many neighbors would be produced faster and more accurately than words with low imageability and few neighbors. Again, some general similarities can be seen amongst the aphasic informants, but there are also many individual differences that should be addressed separately. The control group will, as above, be discussed as one group, but will also be divided in two to investigate possible differences between the older and younger informants.

5.2.1 Error types

An analysis of the errors made by all informants shows that there are six main error types; synonymy, hypernymy, hyponymy, similarity, picture related– and focus errors.

All errors can generally be called semantic errors. Synonymy consists of simple synonyms like *kvinne* for *dame* (both ‘woman’), but this category is also used if the target and response fall within the same semantic field, as when I2 answered *saus* ‘sauce’, and a control subject *grøt* ‘porridge’ for *suppe* ‘soup’ (all these belong to the same semantic field, which in this case goes under the header “liquid/non-solid food that can prototypically be eaten for/with dinner”). When the distance between target and response is bigger, the errors are classified as similarity errors; this can be exemplified by all three aphasic informants when they responded *kaffe* ‘coffee’ to a picture of a bottle of syrup. No similarity were errors found among the answers from the control group. Hyperonyms are seen in answers such as 12’s *figur* ‘figure’ for *leder* ‘leader’, and hyponyms are found in finer specifications such as *anorakk*, *frakk*, or *hettejakke* ‘anorak’, ‘coat’, ‘hoodie’ for *jakke* ‘jacket’ made by informants from both the control group and the informants with aphasia.

Semantic errors can also be responses that are not necessarily related to the target word, but that can be triggered by the picture. This can be illustrated by an example from I1, who answered *kvinne* ‘woman’ instead of *idé* ‘idea’; the picture shows a woman who gets an idea, where the idea is represented with a light bulb above her head (see appendix 3). Such errors are called picture related errors. The last error type is called focus errors, these are closely related to the picture related errors, but differ from them because the informant only focuses on a small, often peripheral part, of the picture. Examples of such errors can be found in I3’s answer of *blomster* ‘flowers’ for *gartner* ‘gardener’, or for instance from one of the control subjects who for the picture of *penger* ‘money’ counted the value of the bank notes and coins, and answered “2002”. Focus errors also entails associations, for instance when I2 associated the check list that figured as picture for *liste* ‘list’ with a program. As pictures are not words it is difficult to know what informants will answer when they see a picture. Both informant I1 and I3, and many of the control subjects produced *statue* ‘statue’ when presented a picture of a *byste* ‘bust’; this is judged as a semantic error because it is not the target word, but the answer in itself is not wrong – a bust is a kind of statue, and *statue* might be more salient, and more frequent than *byste*.

In addition to the abovementioned semantic errors, both I1 and I3 produced a few phonologically deviant forms each; these are cataloged as correct answers. Examples of such phonologically deviant forms are found when the informants produce a word phonologically related to the target word which either results in a non-word or a real word. For instance, I1 produced *siv* /si:v/ ‘reed’ for the target *stativ* ‘rack’, which is a real word, but not the target word, although we can still recognize the target word in this production. Another example of a phonological error which resulted in a non-word can also be found within I1’s answers, as when he produced /ʋaɭɔŋ/ for *ballong* ‘balloon’; the target is still recognizable in the faulty production.

5.2.2 Control group

Most of the errors from the control group are synonymy errors, but there are also a few hyper- and hyponymy, picture related and focus errors. An overview of the errors made by the control subjects can be seen in appendix VII. The errors came from both older and younger informants. Most errors were made in the low imageability word groups. In the low imageable high PND group all words received at least one non-target response; lowest being *penger* ‘money’ with 3 wrong answers, two synonyms and one focus error. Most mistakes were made for *unge* ‘child’ which was erroneously named by 21 of the 30 informants, 17 informants responded with *barn* ‘child’. In the low imageability low PND group all but one word, *idé* ‘idea’ were wrongly named by at least one informant. The word that received least non-target responses was the high imageable low PND word *ekorn* ‘squirrel’ which was named *hare* ‘hare’ by one informant. An overview of the errors from each word group can be seen in Table 18 below.

High IMG High PND	10/15
High IMG Low PND	9/15
Low IMG High PND	15/15
Low IMG Low PND	14/15

Table 18: Number of words per word group that were erroneously named by at least one informant out of 30.

Even for the high imageable words the number of non-target productions is high, but there are a lot less errors per word compared to the low imageable word groups. This can be seen in the following figures (18-21) , where only words that received a non-target response from at least one informant are included in the charts.

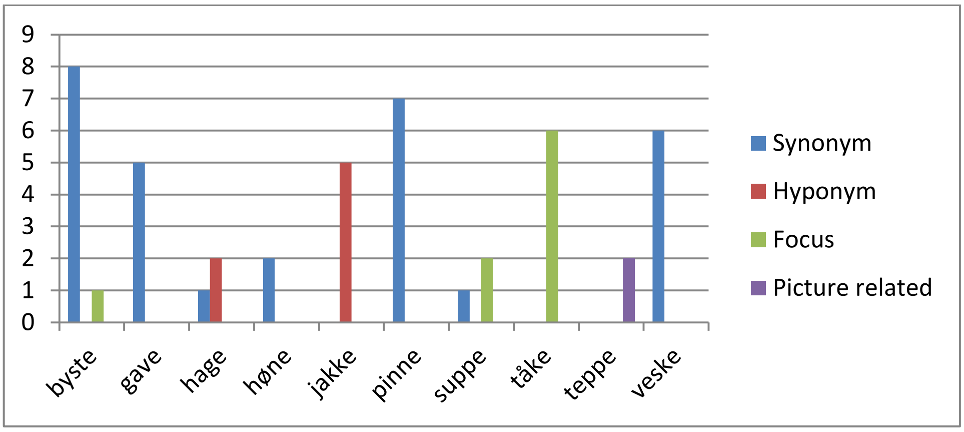

Figure 18: Overview over the individual errors and error types made by the 30 control subjects on the high imageable high PND words in the picture naming test.

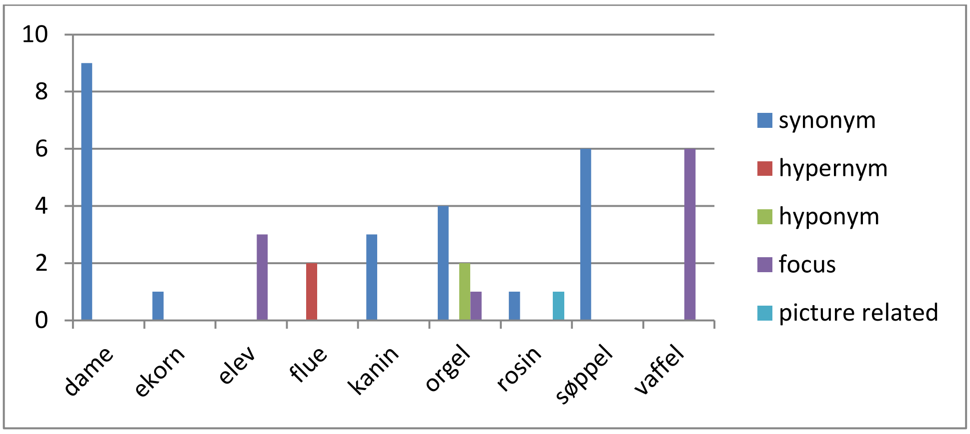

Figure 19: Overview of individual errors for the high imageability low PND words based on answers from the whole control group.

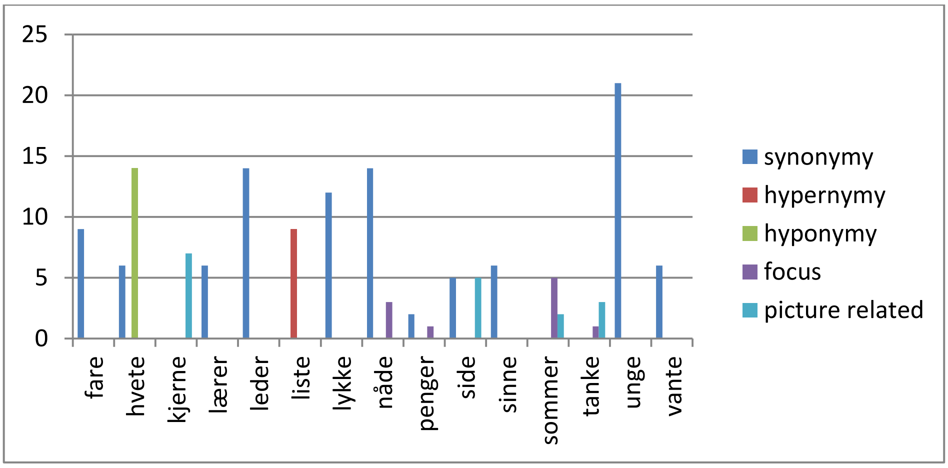

Figure 20: Overview over the individual errors made in the low imageable high PND word group, based on answers from all 30 informants.

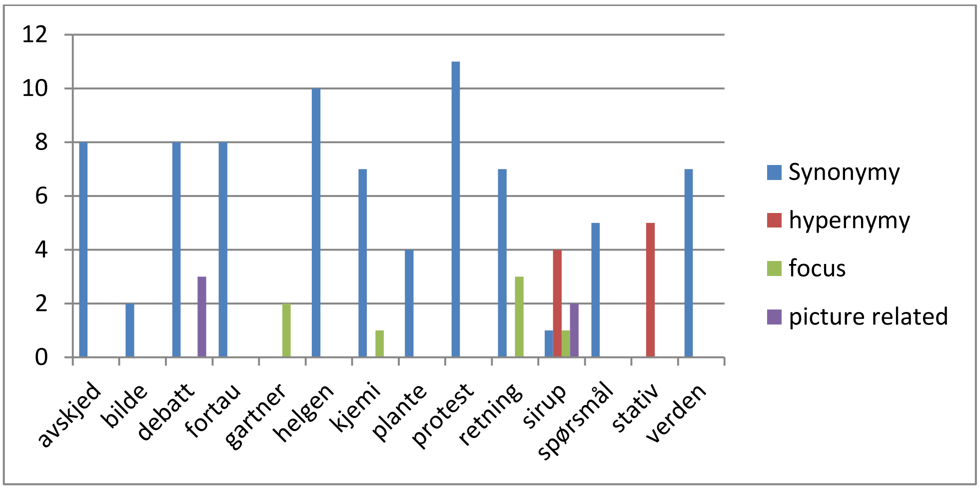

Figure 21: Overview of the individual errors made in the low imageable low PND word group, based on answers from all 30 control subjects.

More errors were made per picture for the low imageable words than for the high imageable words, which would be expected based on previous research which states that high imageable words are more accurately named than low imageable words. Most of the errors from the control group are synonyms with the target word. An overview of the responses can be seen in appendix VII. The results are quite similar when the control group is divided in two groups, one over 50 and one under 50 years of age. Table 19 gives an overview of the errors per word group when the control group is divided based on age.

	All control subjects	Under 50 years	Over 50 years
High IMG High PND	10/15	10/15	10/15
High IMG Low PND	9/15	9/15	8/15
Low IMG High PND	15/15	15/15	15/15
Low IMG Low PND	14/15	13/15	13/15

Table 19: Number of words per word group that was erroneously produced by at least one informant per age group.

Amongst the high imageability words a total of 11 out of 30 words were answered correctly by all 30 informants, for the low imageability words only one word out of 30 were answered correctly. The differences between the older and younger informants are more pronounced in the low PND word groups. In the high imageability low PND word group one of the younger informants erroneously answered *hare* ‘hare’ for *ekorn* ‘squirrel’, which brings the total of errors to 9/15 for the younger informant group, and 8/15 for the older informant group. For the low imageable low PND words, each group made one mistake that the other did not. Two informants from the younger group failed to correctly name *gartner* ‘gardener’ (two focus errors, one *hagearbeid* ‘gardening work’, and one *Blomsterfinn* ‘Flower-Finn’), and two informants from the older group answered with *maleri* ‘painting’ instead of *bilde* ‘picture’.

The average response times for the whole group show that high imageable words are produced faster than low imageable words, and a two-way ANOVA shows that this difference is clearly significant. There is no significant interaction between imageability and phonological neighborhood density in these data. There is a tendency for low PND words to be produced faster than high PND words in this material. The response times show that high PND words, which were expected to be named faster than low PND words if PND is a facilitative factor, are produced more slowly, both in high and low imageability environments. Table 20 gives an overview of the response latencies for the 30 normal control subjects for the picture naming task, and table 21 shows the F and P values for imageability and PND and the interactions between the two factors from the ANOVA.

IMG+PND	RT (in msec.)
HiIMG+HiPND	3374.41
HiIMG+LoPND	3235.5
LoIMG+HiPND	4404.38
LoIMG+LoPND	4217.74

Table 20: Overview of the response latencies for the four words groups in the picture naming test by all 30 control subjects.

	F value	P value
IMG	74.024	0.0000000000000002
PND	1.937	0.164
IMG:PND	0.0416	0.838

Table 21: F and P values for Imageability, Phonological Neighborhood Density and the interaction between the two, from the two-way ANOVA for all 30 control subjects.

An overview of the response times for all subjects on the four word groups can be seen in the boxplot in Figure 22.

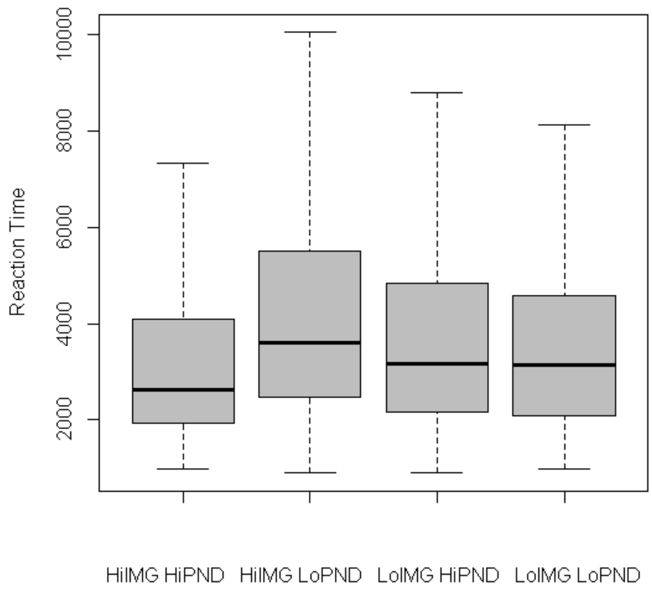

Figure 22: Boxplot showing the distribution of reaction times on the picture naming experiment by all 30 control subjects.

When the group is divided by age, we can see that for the younger informants low PND words were produced faster than high PND words, which goes against what has been found in previous research on phonological neighborhood density. Imageability behaves as predicted; low imageable words have longer response times than high imageable words. An overview of the reaction times for the 15 youngest informants can be seen in Table 22 and Figure 23 below.

IMG+PND	RT (in msec.)
HiIMG+HiPND	3296.1
HiIMG+LoPND	3155.26
LoIMG+HiPND	4314.91
LoIMG+LoPND	4080.41

Table 22: Overview of the response latencies for the four words groups in the picture naming test by the 15 youngest control subjects.

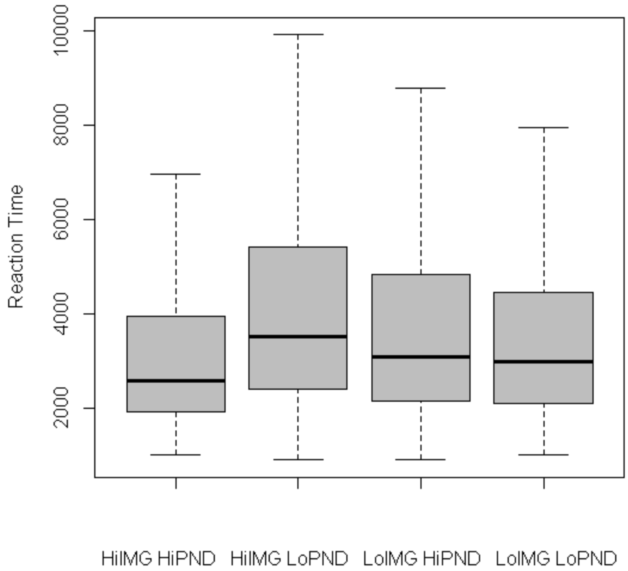

Figure 23: Overview of the distribution of Reaction Times on the picture naming test as produced by the 15 youngest informants of the control group.

For the younger informants there is a statistically significant difference between the response latencies for high- and low imageable words, but not for PND. Furthermore, there is no significant interaction between the two factors, as can be seen in Table 23 below.

	F value	P value
IMG	6.189	0.013
PND	0.024	0.876
IMG:PND	0.117	0.732

Table 23: F and P values for Imageability, Phonological Neighborhood Density and the interaction between the two, from the two-way ANOVA for the 15 youngest informants in the control group.

The significance for imageability may again suggest that imageability is more important for a word's retrieval than phonological neighborhood density.

The same pattern is seen when for the older informants. High imageable low PND words are produced faster than high imageable high PND words, and low imageable low PND words are produced faster than low imageable low PND words, and there is a significant difference between high- and low imageability words, but not for PND and there is no interaction between the two factors (cf. Tables 24 and 25). A graphic representation of the reaction times can be seen in Figure 24.

IMG+PND	RT (in msec.)
HiIMG+HiPND	3452.8
HiIMG+LoPND	3315.73
LoIMG+HiPND	4493.84
LoIMG+LoPND	4355.1

Table 24: Overview of the response latencies for the four words groups in the picture naming test by the 15 oldest control subjects.

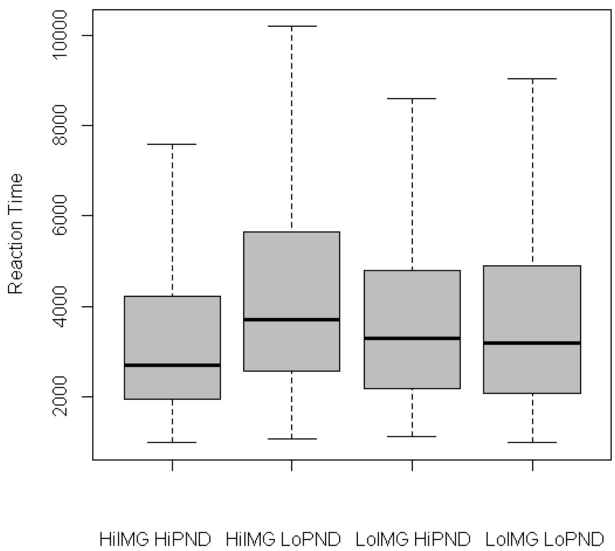

Figure 24: Overview of the response latencies for all four word groups in the picture naming task, as given by the 15 oldest informants.

	F value	P value
IMG	6.189	0.013
PND	0.024	0.876
IMG:PND	0.117	0.732

Table 25: F and P values for Imageability, Phonological Neighborhood Density and the interaction between the two, from the two-way ANOVA for the 15 oldest informants in the control group.

The next step would be to see if age could be a determining factor in this test. Another analysis of variance showed that, as with the lexical decision task, age is not a significant factor. Table 26 shows the results from the second ANOVA, where age was taken as an extra independent variable.

	F value	P value
Age	0.672	0.412
IMG	24.142	0.0000009699
PND	3.301	0.069
Age:IMG	0.347	0.555
Age:PND	0.054	0.815
IMG:PND	0.688	0.406
Age:IMG:PND	0.071	0.789

Table 26: F and P values for age, imageability, phonological neighborhood density and the interaction between the three factors, from the ANOVA.

To sum up the results from the control group it seems that when it comes to accuracy, high imageable words are named more accurately than low imageability words, and there were more errors on the low PND words from either imageability class. Most of the errors were found in the low imageability high PND word group, where all words were named wrongly by at least one informant. An overview can be found in appendix VII. With regard to reaction times, it shows that the control group, both as a whole and when divided by age, are faster at producing words from the high imageable low PND word group, followed by the high imageable high PND, and low imageable low PND group before the low imageable high PND group. Imageability is the only factor that behaves according to the predictions, as there are both shorter reaction times and higher accuracy for the words from this group.

5.2.3 Aphasic data

All three aphasic informants show a great deal of semantic errors, that is, they produce words that are semantically similar to the target word rather than the target word itself. None of the three informants managed to name all the pictures. I1 and I2 passed on one picture each and I3 on three pictures. I1 could not think of a word for the picture *protest* ‘protest’, I2 had trouble remembering the word *rosiner* ‘raisins’ and I3 passed on the words *stativ* ‘rack’, *kjerne* ‘core’, and *fortau* ‘pavement’, all but *rosiner* have low imageability scores.

In addition to the errors mentioned above, I1 made some mistakes that can be classified as perseverations, which means that a word, once activated, is being erroneously repeated. This can be seen in how he answers *kvinne* ‘woman’ or *mann* ‘man’ to all pictures with an animate referent. With this in mind, it is hard to determine whether the response *kvinne* for the target *idé* ‘idea’ was a preservation error or a focus error.

All three made most of their errors on words with low imageability. I2 and I3 made more mistakes in the low imageability high PND group, and I1 made just as many mistakes in both groups. The results can be seen in Table 27 below.

	I1	I2	I3
Hi IMG +Hi PND	8/15	9/15	8/15
Hi IMG + Lo PND	7/15	8/15	3/15
Lo IMG + Hi PND	10/15	14/15	11/15
Lo IMG + Lo PND	10/15	10/15	10/15

Table 27: Numbers of non-target responses (out of 15 for each word group) for all three informants with aphasia on the picture naming test.

All three informants made more non-target productions for words with high phonological neighborhood density, which was not to be expected following the literature on the subject. As outlined in chapter 2.4.2 on previous research, the high PND words should in fact be more accurately produced than the low PND words, but this is not the case for these three informants. The results for imageability, however, are as predicted: High imageable nouns were faster and more accurately produced than low imageability nouns. This might suggest that imageability is more influential than phonological neighborhood density, and the effects of imageability are therefore more pronounced than the effects of PND.

I1 was the fastest, with an average of 4925 msec per word, followed by I3 whose average reaction time was 7040 msec, and I2 had an average response time of 14191 msec per word. One reason for this is that I2 more often than not explained the object’s use as well as giving its name, which can be illustrated by his answer when presented with a picture of a pair of gloves: “Det brukes til å holde hendene varme med når det er kaldt ute. Et håndkle, nei ikke det. Til hendene. Hånd- Hansker er det."[13] He also made more false starts, both on correct and erroneous productions, than I1 and I3, as seen in his answer to a picture of a bag: "En ves- nei, det er ikke en veske, det er et annet ord som er mye vanligere enn veske. Men det husker jeg ikke."[14] These answers, and the many non-target responses made by these informants, show that it is problematic to judge the performance of the speakers with aphasia based on reaction times, the accuracy of their responses needs to be weighted heavier than their response latencies. Answers from all three aphasic informants can be found in appendices VIII-X.

I2 was generally slower than the two others, and he made more focus errors; on a picture of *bilde* 'picture' he focused on what was on the pictured picture (see appendix 3), and produced *marka* 'the forest', another example is from *åker* 'crop field' where he answered *en plante* 'a plant'. Table 28 below shows the average reaction times for the three informants on each word group.

	I1	I2	I3
Hi IMG +Hi PND	7284	14522	6430
Hi IMG + Lo PND	2565	15096	5796
Lo IMG + Hi PND	3720	11324	8859
Lo IMG + Lo PND	6080	15823	7166

Table 28: Average reaction times (in msec.) per informant per word group on the picture naming task.

The informants with aphasia show fairly similar patterns when it comes to accuracy, high imageability words were named right more than low imageability words, high imageability low PND words were named most accurately by all three informants, and most errors were found in the low imageability high PND word group. When it comes to reaction times there was a great deal of individual variation between the tree informants. They are all faster at producing high imageable words with few neighbors before high imageable words with many neighbors, followed by low imageable words with low PND, and they are all slowest at producing low imageable words with many phonological neighbors.

[13] "It is used to keep the hands warm when it is cold outside. A towel [literally *hand cloth*], no, not that. For the hands. A tow- they are gloves."
[14] "A ba- no, it is not a bag. There is another word that is much more common than bag. But I can't remember it"

5.2.4 Summary

Similar to the results seen in the lexical decision task, the results from the picture naming task are comparable across informant groups, especially when it comes to accuracy. Overall, all informants made gave more non-target responses for words with low imageability and high PND, followed by the low imageability low PND word group. Most correct answers were given for words from the high imageability low PND word group. As a group, and when divided by age, the control subjects named words from high imageability low PND environments faster than high imageable high PND words, followed by low imageable low PND words, and the least accurate word group by all informant groups (informants with aphasia and the control group, both as a whole and when divided by age) were the low imageable high PND words.

For both the informants with aphasia and the control group imageability behaves according to the predictions, but phonological neighborhood density show a different pattern than what was expected. This is similar to the results in the visual and auditory lexical decision task.

6 Discussion and closing comments

In this final chapter I will discuss the recent findings, and make some concluding remarks. First I will look at what exactly the results mean, and then I will try to fit them in to the models of speech production and perception discussed in chapter 3, and finally I make a general summary where I discuss the findings in light of my research questions, before ending with some suggestions for further research.

6.1 General discussion

Although the results showed no statistically significant interaction between imageability and phonological neighborhood density in either speech production or perception, for either of the informant groups, there is a tendency for high imageability words to be recognized and produced faster than low imageability words. Also, when the imageability is low, high PND does slow down not only the recognition, but also the production of words. The similar patterns observed across word groups and informant groups show us that there is a reason to study normal and atypical language behavior together. The results from this study can be taken to suggest that the fundamental similarities observed between the informants with and without aphasia speech processing is controlled by the same mechanisms in speaker with acquired language impairments and neurologically healthy speakers.

The significant differences between high and low imageability words show us that imageability is a semantic/conceptual factor that affects the processing speed and accuracy for both neurologically healthy and language impaired speakers.

6.1.1 Perception

In the visual and auditory lexical decision task, the only significant difference was between high- and low imageable words. There was no significant interaction between the two factors, and there was no significant difference between high and low PND words. This might suggest that imageability is more important than phonological neighborhood density in perception.

The only significant factor for either group in this task was imageability. A predicted age factor within the control group, based on the findings of Simonsen et al. (In press), that informants over the age of 50 years would show significant and systematic differences regarding imageability from the informants under 50 years, was not replicated in this study.

If there had been an interaction between imageability and phonological neighborhood density, the difference in reaction times between high and low PND words for low imageable words would have been greater. The tendency towards longer reaction times for high PND low imageability words, which is found both in the control group and among the aphasic informants, is not significant in itself, but should be investigated further with a larger dataset and more informants. The results suggest that imageability is more important in perception than phonological neighborhood density.

6.1.2 Production

The results from the picture naming task show that there is a significant effect of imageability, but not of phonological neighborhood density, and there is no interaction between the two factors. There was no difference between the informants with aphasia and the control group. When analyzing the control data as two groups, the results were similar. Age did not influence the results in any way. There was, however, a tendency towards high PND words being produced slower than low PND words, which is the opposite of what has been found in previous research.

When it comes to accuracy, the word group with most correct answers was the high imageability high PND group, closely followed by the high imageability low PND group. Most erroneous productions were found in the low imageability low PND word group for both the control subjects and the speakers with aphasia. For all informant groups (informants with aphasia, and the control group as a whole and when divided by age) most non-target productions were produced for words with high phonological neighborhood density.

The results were difficult to analyze because of the many mistakes made by multiple participants in this study, but the results suggest that imageability overrules phonological neighborhood density in production, as well as in perception, at least when it comes to speed of production. An interesting result is that in this dataset, phonological neighborhood density seems to slow down, rather than speed up production which would have been the predicted results based on previous research. Furthermore, all informant groups make more mistakes naming high PND words than words with low PND. This result is different from what can be expected based on earlier research in the field (Janse, 2009, Middleton and Schwartz, 2010, Stemberger, 2004, Tyler et al., 2000, Vitevitch, 2002, Westbury and Moroschan, 2009).

The unexpected results for phonological neighborhood density in production raise a quite interesting question; why does this material trigger results that so clearly go against earlier findings on phonological neighborhood density? The words were carefully chosen out, based on frequency, number of syllables, imageability ratings and phonological neighborhood density, and still the results show an opposite tendency from what has been the consensus for decades. The main reason for this could be that I had to base the word selection on words that already had imageability ratings. When I calculated the phonological neighborhood density for these words, it was clear that the distribution between high and low PND for the words with imageability ratings was uneven, and the difference between which words have high and low PND may have been too small.

6.1.3 Comparing informants with and without aphasia

Initially I mentioned that there is a rationale behind studying normal language processes in comparison with language processes observed in speakers who have an acquired language disorder. Researchers who study normal language processes in light of atypical language processes do so because they believe there are some underlying processes in the brain that are similar to all people, and which can get selectively impaired. Another reason why acquired speech disorders can shed light on normal, unimpaired language use is that the difficulties observed in aphasia can be seen as exaggerations of the problems that normal speakers may encounter (Aitchison, 1987, Bates and Goodman, 1997).

The results from this study show very similar results between the informant groups, remarkably so in the picture naming test, where the control subjects had to complete a distractor task. This suggests that there are underlying structures that work in the same way for both damaged and neurologically healthy brains, and that the problems observed for the control subjects when stressed are similar to the problems observed for the three speakers with aphasia.

6.2 The results in light of speech processing models

In the following two chapters I will look back to the four models of speech processing that were introduced in chapter 3, and see if either can explain some of the findings in this study.

6.2.1 Perception

The Neighborhood Activation Model (Luce and Pisoni, 1998) was not able to give any predictions for interactions between imageability and PND, as it does not cover semantic factors at all. The distributed model by Gaskell and Marslen-Wilson (Gaskell and Marslen-Wilson, 1997), however, suggested that semantics and phonology operate in parallel and interact during speech perception. This means that high imageability words should be able to affect the otherwise difficult high PND words, and speed up the recognition. This is seen in the results from the control group, where there is no real difference between recognition of high- and low PND words if the imageability is high.

6.2.2 Production

As there is no significant interaction between imageability and PND amongst the results for the production task, it is hard to accept the prediction posed by Dell et al.'s model (Dell et al., 1997), that imageability and PND will affect each other. Levelt et al.'s model (Levelt et al., 1999) would suggest that imageability and phonological neighborhood density are independent of each other, as they operate on two separate levels with no bi-directional interaction. This could explain why there is no interaction between imageability and phonological neighborhood density in the results, but it cannot account for why high PND words are named slower than low PND words. Neither of the models can account for the findings in this study in a satisfactory manner.

6.3 Summing up

The results show that there is no interaction between imageability and phonological neighborhood density in perception, at least no when a word's imageability is high. Both in perception and production there is a statistical significance for high imageable words to be recognized and produced faster than low imageable words. There is also a tendency towards low imageable words with low PND to be recognized faster than low imageable words with high PND in perception. Furthermore it seems like high phonological neighborhood density slows down production and increases the number of non-target productions in picture naming. This suggests that the semantic factor or imageability overrides the phonological factor of PND, both in production and perception.

These results answer some of my research questions, as they were outlined in chapter 3.3 above. The first general question I posed was if the Norwegian results will follow the same pattern as seen in previous research. For imageability the results prove that there is no real difference between Norwegian and other languages; high imageable words are recognized faster than low imageable words, and imageability is also a facilitative factor in naming, with shorter reaction times and less errors for high imageability nouns than for low imageability nouns. Phonological neighborhood density, however, does not fit the pattern laid out in the literature when it comes to naming. High PND words should be faster to produce and with fewer errors than low PND words, this is not the case in this material. When it comes to perception it does look like the low PND words are recognized somewhat faster than high PND words, as it would be expected based on previous research. This difference was, however, not statistically significant.

The second question I posed was whether the two effects were equally facilitative, or if one factor would override the other. In both the perception and production task there were significantly shorter reaction times for high imageable words than for low imageable words, but no significant difference between high and low PND words. This suggests that imageability is more important for a word's production and perception than its phonological neighborhood density.

I further asked if there would be any differences in naming latencies and/or error production for the in-between groups (high imageability and low PND vs. high PND and low imageability), and there were. Low imageable words with high phonological neighborhood densities were named slower than high imageable words with low PND, and with more errors or non-target productions.

The last question I wanted to answer was with regard to perception: would high PND slow down the recognition of high imageable words, and would low imageable words with high PND be recognized substantially slower than other words? The answer to this is no, phonological neighborhood density does not affect high imageable words at all. There is, however, a tendency towards low imageable words to be affected by phonological neighborhood density, but this tendency is not statistically significant.

6.4 Ideas for further research

The data set used in this study is rather small, and the number of informants a bare minimum, this might of course have affected the results. Further research into imageability and phonological neighborhood density should take that into account, and try the same with a bigger data set and more informants. It could also be an idea to check the number of real-word neighbors for the non-words that were mistaken for real words (such as *spektes*, *simmer* and *stipe* amongst others), and see if that could influence the results. The phonological neighborhood density and imageability for the non-target productions should also been controlled. That, together with frequency might give an answer to why some words were produced rather than others. It might also be of interest to look into why the nouns with high phonological neighborhood density in this study were produced slower than the high PND nouns, as this is not in accordance with previous research in the field. The main reason for this is probably that there is not a clear enough difference between high and low PND words in this material. Researcher investigating the interactions between imageability and phonological neighborhood density in the future should make sure that make sure that the material allows for a bigger difference between high and low PND words.

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Appendices

Appendix I: Words and non-words used in lexical decision experiment

HiIMG HiPND	Translation	HiIMG LoPND	Translation	LoIMG HiPND	Translation	LoIMG LoPND	Translation
Briller	Glasses	Flaske	Bottle	Gåte	Riddle	Effekt	Effect
Bøtte	Bucket	Genser	Sweater	Fure	Furrow	Fabel	Fable
Gate	Street	Kaffe	Coffee	Krise	Crisis	Grøde	Crop
Kjeller	Basement	Kråke	Crow	Rolle	Role	Kaos	Chaos
Pose	Bag	Pensel	Paint brush	Måte	Manner	Kilo	Kilo
Pære	Pear	Tavle	Blackboard	Tabbe	Mistake	Rolle	Role
Skole	School	Tekstil	Textile	Tante	Aunt	Vilje	Will
Tønne	Barrel	Truse	Knickers	Type	Type	Yrke	Profession

Non-words	Alfum	Blesse	Bølde	Datin
	Essekt	Fakmut	Fibbe	Gaffi
	Hetall	Karke	Kjebbe	Kryse
	Megrep	Midlem	Mineng	Pelter
	Permon	Rystem	Saffe	Sedrag
	Sibron	Simmer	Skete	Skobe
	Sogme	Spektes	Stipe	Strote
	Tirat	Trågge	Vendu	Vitor

Appendix II: Words used in picture naming experiment

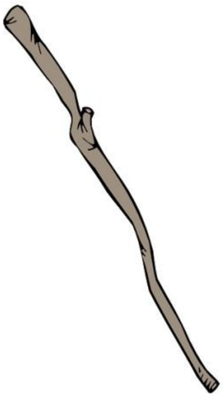
HiIMG HiPND	Trans.	HiIMG LoPND	Trans.	LoIMG HiPND	Trans.	LoIMG LoPND	Trans.
Byste	Bust	Ballong	Balloon	Fare	Danger	Avskjed	Farewell
Gave	Gift	Dame	Lady	Hvete	Wheat	Bilde	Picture
Gjerde	Fence	Ekorn	Squirrel	Kjerne	Core	Debatt	Debate
Hage	Garden	Elev	Pupil	Leder	Leader	Fortau	Pavement
Hode	Head	Flue	Fly	Liste	List	Gartner	Gardener
Høne	Hen	Kanin	Rabbit	Lykke	Happiness	Helgen	Saint
Jakke	Jacket	Melon	Melon	Lærer	teacher	Idé	Idea
Løve	Lion	Nøkkel	Key	Nåde	Mercy	Kjemi	Chemistry
Mage	Stomach	Orgel	Organ	Penger	Money	Plante	Plant
Nese	Nose	Rosin	Raisin	Side	Page	Protest	Protest
Pinne	Stick	Sukker	Sugar	Sinne	Anger	Retning	Direction
Suppe	Soup	Søppel	Garbage	Sommer	Summer	Sirup	Syrup
Teppe	Carpet	Tiger	Tiger	Tanke	Thought	Spørsmål	Question
Tåke	Mist	Vaffel	Waffle	Vante	Glove	Stativ	Rack
Veske	Bag	Åker	Crop field	unge	kid	Verden	World

Appendix III: Examples from the picture naming test

High imageability high PND

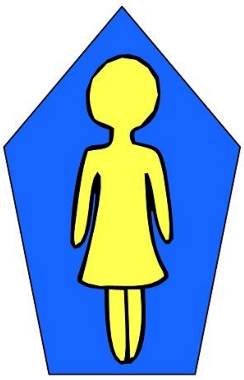
Byste (bust), jakke (jacket), pinne (stick), suppe (soup).






High imageability low PND

Dame (woman), ballong (balloon), ekorn (squirrel), åker (crop field).



Low imageability high PND

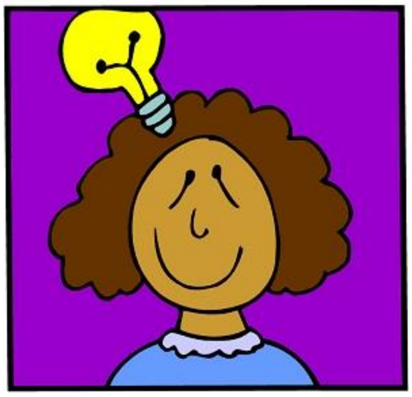
Leder (leader), penger (money), unge (child), vanter (gloves).

Low imageability high PND

Bilde (picture), gartner (gardener), idé (idea), sirup (syrup).



Appendix IV: I1's responses to the auditory and visual lexical decision test

IMG	PND	Word	I1 RT
Hi	Hi	briller	1256
Hi	Hi	bøtte	1153
Hi	Hi	kjeller	1440
Hi	Hi	gate	1218
Hi	Hi	pose	1344
Hi	Hi	pære	1276
Hi	Hi	skole	1390
Hi	Hi	tønne	1236
Hi	Lo	flaske	1245
Hi	Lo	genser	1298
Hi	Lo	kaffe	1249
Hi	Lo	kråke	1270
Hi	Lo	pensel	1288
Hi	Lo	tavle	1326
Hi	Lo	tekstil	1504
Hi	Lo	truse	1205
Lo	Hi	fure	1718
Lo	Hi	gåte	1276
Lo	Hi	krise	1305
Lo	Hi	måte	1868
Lo	Hi	rolle	1563
Lo	Hi	tabbe	1233
Lo	Hi	tante	1143
Lo	Hi	type	1714
Lo	Lo	effekt	1133
Lo	Lo	fabel	1233
Lo	Lo	grøde	9574
Lo	Lo	kaos	1262
Lo	Lo	kilo	1463
Lo	Lo	regel	1274
Lo	Lo	vilje	1258
Lo	Lo	yrke	1127
NW	NW	Alfum	1595
NW	NW	Blesse	1653
NW	NW	Bølde	1946
NW	NW	Datin	1519
NW	NW	Essekt	4055
NW	NW	Fakmut	1695
NW	NW	Fibbe	1652
NW	NW	Gaffi	1629
NW	NW	Hetall	2287

NW	NW	Karke	4543
NW	NW	Kjebbe	1871
NW	NW	Kryse	3101
NW	NW	Megrep	1692
NW	NW	Midlem	1540
NW	NW	Mineng	2757
NW	NW	Pelter	1877
NW	NW	Permon	1765
NW	NW	Rystem	2103
NW	NW	Saffe	1676
NW	NW	Sedrag	2098
NW	NW	Sibron	1611
NW	NW	Simmer	1404
NW	NW	Skete	2296
NW	NW	Skobe	2095
NW	NW	Sogme	1943
NW	NW	Spektes	2850
NW	NW	Stipe	2343
NW	NW	Strote	1612
NW	NW	Tirat	1596
NW	NW	Trågge	1768
NW	NW	Vendu	1748
NW	NW	Vitor	1734

Average all	1826,5
Average HiIMG+HiPND	1289
Average HiIMG+LoPND	1298
Average LoIMG+HiPND	1477
Average LoIMG+LoPND	2290

Appendix V: I2's responses to the auditory and visual lexical decision test

IMG	PND	Word	I2 RT
Hi	Hi	briller	2521
Hi	Hi	bøtte	2215
Hi	Hi	kjeller	2150
Hi	Hi	gate	2230
Hi	Hi	pose	3008
Hi	Hi	pære	4027
Hi	Hi	skole	1852
Hi	Hi	tønne	2571
Hi	Lo	flaske	1950
Hi	Lo	genser	2403
Hi	Lo	kaffe	2118
Hi	Lo	kråke	2175
Hi	Lo	pensel	2760
Hi	Lo	tavle	2177
Hi	Lo	tekstil	4042
Hi	Lo	truse	3790
Lo	Hi	fure	2621
Lo	Hi	gåte	2589
Lo	Hi	krise	2876
Lo	Hi	måte	2449
Lo	Hi	rolle	3184
Lo	Hi	tabbe	3805
Lo	Hi	tante	7240
Lo	Hi	type	2646
Lo	Lo	effekt	2093
Lo	Lo	fabel	2329
Lo	Lo	grøde	6918
Lo	Lo	kaos	2044
Lo	Lo	kilo	5567
Lo	Lo	regel	3454
Lo	Lo	vilje	2671
Lo	Lo	yrke	1983
NW	NW	Alfum	4678
NW	NW	Blesse	11212
NW	NW	Bølde	7606
NW	NW	Datin	6760
NW	NW	Essekt	5421
NW	NW	Fakmut	3910
NW	NW	Fibbe	5736
NW	NW	Gaffi	4351
NW	NW	Hetall	4591
NW	NW	Karke	3362

NW	NW	Kjebbe	3750
NW	NW	Kryse	3957
NW	NW	Megrep	3766
NW	NW	Midlem	7428
NW	NW	Mineng	3675
NW	NW	Pelter	4544
NW	NW	Permon	13510
NW	NW	Rystem	16848
NW	NW	Saffe	13230
NW	NW	Sedrag	7066
NW	NW	Sibron	3046
NW	NW	Simmer	21021
NW	NW	Skete	8406
NW	NW	Skobe	4875
NW	NW	Sogme	11619
NW	NW	Spektes	29861
NW	NW	Stipe	4689
NW	NW	Strote	6170
NW	NW	Tirat	4439
NW	NW	Trågge	3390
NW	NW	Vendu	5135
NW	NW	Vitor	4668

Average all	5299,656
Average HiIMG+HiPND	2571
Average HiIMG+LoPND	2676
Average LoIMG+HiPND	3426
Average LoIMG+LoPND	3382

Appendix VI: I3's responses to the auditory and visual lexical decision test

IMG	PND	Word	I3 RT
Hi	Hi	briller	1447
Hi	Hi	bøtte	1342
Hi	Hi	kjeller	1484
Hi	Hi	gate	1720
Hi	Hi	pose	1226
Hi	Hi	pære	1201
Hi	Hi	skole	1501
Hi	Hi	tønne	1144
Hi	Lo	flaske	1224
Hi	Lo	genser	1783
Hi	Lo	kaffe	1335
Hi	Lo	kråke	1257
Hi	Lo	pensel	2087
Hi	Lo	tavle	1482
Hi	Lo	tekstil	1657
Hi	Lo	truse	1537
Lo	Hi	fure	2079
Lo	Hi	gåte	1352
Lo	Hi	krise	1931
Lo	Hi	måte	1265
Lo	Hi	rolle	1234
Lo	Hi	tabbe	1950
Lo	Hi	tante	1394
Lo	Hi	type	1718
Lo	Lo	effekt	1156
Lo	Lo	fabel	1380
Lo	Lo	grøde	4813
Lo	Lo	kaos	1613
Lo	Lo	kilo	1472
Lo	Lo	regel	1434
Lo	Lo	vilje	1504
Lo	Lo	yrke	1208
NW	NW	Alfum	1442
NW	NW	Blesse	1253
NW	NW	Bølde	1998
NW	NW	Datin	1419
NW	NW	Essekt	3728
NW	NW	Fakmut	2247
NW	NW	Fibbe	2351
NW	NW	Gaffi	1949
NW	NW	Hetall	2062
NW	NW	Karke	3239
NW	NW	Kjebbe	6285

NW	NW	Kryse	2853
NW	NW	Megrep	1846
NW	NW	Midlem	1836
NW	NW	Mineng	1517
NW	NW	Pelter	2015
NW	NW	Permon	2770
NW	NW	Rystem	1818
NW	NW	Saffe	1874
NW	NW	Sedrag	1525
NW	NW	Sibron	2125
NW	NW	Simmer	2755
NW	NW	Skete	1217
NW	NW	Skobe	1843
NW	NW	Sogme	1532
NW	NW	Spektes	2620
NW	NW	Stipe	2052
NW	NW	Strote	2638
NW	NW	Tirat	1652
NW	NW	Trågge	1379
NW	NW	Vendu	1611
NW	NW	Vitor	1663

Average all	1875,6875
Average HiIMG+HiPND	1383
Average HiIMG+LoPND	1545
Average LoIMG+HiPND	1655
Average LoIMG+LoPND	1822

Appendix VII: Non-target responses by the control subjects to the picture naming experiment

IMG+PND	Target	Response	Translation	No. Of answers	Notes
Hi+Hi	Byste	Statue	Statue	8	Synonymy
		Filosof	Philosopher	1	Focus
Hi+Hi	Gave	Presang	Present	5	Synonymy
Hi+Hi	Hage	Kjøkkenhage	Kitchen garden	2	Hyponomy
		Eiendom	property	1	Synonymy
Hi+Hi	Høne	hane	Rooster	2	Synonymy
Hi+Hi	Jakke	Anorakk	Anorak	3	Hyponomy
		Parkas	Parka	1	Hyponomy
		Hettejakke	Hoodie	1	Hyponomy
Hi+Hi	Pinne	Kvist	Teig	4	Synonymy
		Stokk	Stick	2	Synonymy
		Stokk	Stick	1	Synonymy
Hi+Hi	Suppe	Suppeterrin	Soup Tureen	1	Synonymy
		Suppekjele	Soup Kettle	1	Synonymy
		Grøt	Porrige	1	
Hi+Hi	Tåke	Skog	Forest	6	Focus
Hi+Hi	Teppe	Lommetørkle	Handkerchief	1	Picture related
		Pute	Cussion	1	Picture related
Hi+Hi	Veske	Bag	Bag	4	Synonymy
		Ransel	Satchel	2	Synonymy
Hi+Lo	Dame	Kvinne	Woman	9	Synonymy
Hi+Lo	Ekorn	Hare	Hare	1	Synonymy
Hi+Lo	Elev	Tavle	Blcakboard	2	Focus
		Mattematikk	Mathemathics	1	Focus
Hi+Lo	Flue	Insekt	Insect	2	Hypernomy
Hi+Lo	Kanin	Hare	Hare	3	Synonymy
Hi+Lo	Orgel	Pipeorgel	Pipe organ	3	Synonymy
		Kirkeorgel	Church organ	2	Hyponomy
		Orgel piper	Organ pipes	1	Focus
		Flygel	Grand piano	1	Synonymy
Hi+Lo	Rosin	Drops	Candy	1	Synonymy
		Maur	Ants	1	Picture related
Hi+Lo	Søppel	Søppelkasse	Garbage can	3	Synonymy
		Søppeldunk	Garbage can	2	Synonymy
		Søppeltønner	Garbage barrles	1	Synonymy

Hi+Lo	Vaffel	Vaffelhjerter	Hearts of Waffles	6	Focus
Lo+Hi	Fare	Stoppskilt	Stop sign	4	Synonymy
		Farekilt	Danger sign	3	Synonymy
		Skilt	Sign	2	Synonymy
Lo+Hi	Hvete	Korn	Grains	8	Hyponymy
		Havre	Barley	4	Synonymy
		Mais	Corn	2	Synonymy
Lo+Hi	Kjerne	Magma	Magma	4	Picture related
		Jordas indre	Centre of the earth	2	Picture related
		Jorda	The Earth	1	Picture related
Lo+Hi	Lærer	Lærerinne	Female teacher	4	Synonymy
		Frøken	Miss	2	Synonymy
Lo+Hi	Leder	Veiviser	Guide / location finder	6	Synonymy
		Vinner	Winner	5	Synonymy
		Sjef	Boss	3	Synonymy
Lo+Hi	Liste	Handlelist	Shopping list	4	Hypernymy
		Huskeliste	Reminder	3	Hypernymy
		Huskelapp	Reminder	2	Hypernymy
Lo+Hi	Lykke	Glede	Happiness	8	Synonymy
		Glad	Happy	4	Synonymy
Lo+Hi	Nåde	Bønn	Prayer	14	Synonymy
		Drap	Murder	3	Focus
Lo+Hi	Penger	Selder	Bank notes	2	Synynomy
		2002	2002	1	Focus
Lo+Hi	Side	Ark	Paper	4	Synynomy
		Skrivebok	Writing pad	2	Picture related
		Blad	Page/leaf	1	Synonymy
Lo+Hi	Sinne	Sinna	Angry	3	Synonymy
		Sur	Grumpy	2	Synonymy
		Misfornøyd	Unhappy	1	Synonymy
Lo+Hi	Sommer	Sol	Sun	4	Focus
		Skog	Forest	2	Picture related
		Sommerlandskap	Summer landscape	1	Focus
Lo+Hi	Tanke	Tegneserie	Cartoon	3	Picture related
		Snakkeboble	Speech bubble	1	Focus
Lo+Hi	Unge	Barn	Child	17	Synonymy
		Mann	Man	3	Synonymy

		Fyr	Guy	1	Synonymy
Lo+Hi	Vante	Hansker	Gloves	5	Synonymy
		Votter	Mittens	1	Synonymy
Lo+Lo	Avskjed	Farvell	Farewell	6	Synonymy
		Hilse	Greet	3	Synonymy
		Vinke	Wave	2	Synonymy
		Reise	Travel	1	Synonymy
Lo+Lo	Bilde	Maleri	Painting	2	Synonymy
Lo+Lo	Debatt	Spørreprogram/ quiz	Quiz show	5	Synonymy
		Diskusjon	Discussion	3	Synonymy
		Talkshow	Talkshow	2	Picture related
		Konsert	Concert	1	Picture related
Lo+Lo	Fortau	Vei	Road	4	Synonymy
		Sti	Path	3	Synonymy
		Gangvei	Walkway	1	Synonymy
Lo+Lo	Gartner	Blomsterfinn	«Flower Finn»	1	Focus
		Hagearbeid	Gardening	1	Focus
Lo+Lo	Helgen	Prest	Priest	3	Synonymy
		Apostel	Apostle	3	Synonymy
		Jesus	Jesus	2	Synonymy
		Disippel	disiple	1	Synonymy
		Gud	God	1	Synonymy
Lo+Lo	Kjemi	Laboratorium	Laboratory	5	Synonymy
		Eksperiment	Experiment	2	Synonymy
		Medisinskap	Medicine cabinet	1	Focus
Lo+Lo	Plante	Potteplante	Potted plant	3	Synonymy
		Palme	Palm	1	Synonymy
Lo+Lo	Protest	Demonstrasjon / demonstrasjons-tog	Demonstration/ demonstration parade	10	Synonymy
		Streik	strike	1	Synonymy
Lo+Lo	Retning	Skilt	Sign	7	Synonymy
		Stolpe	Pole	3	Picture related
Lo+Lo	Sirup	Lønnesirup	Maple Syrup	4	Hypernymy
		Flaske	Bottle	2	Focus
		Honning	Honney	1	Synonymy
		Likør	Liqueur	1	Picture related
		Whiskey	Whiskey	1	Picture related
Lo+Lo	Spørsmål	Spørsmålstegn	Questionmark	5	Synonymy
Lo+Lo	Stativ	Klesstativ	Clothing rack	3	Hypernymy

		Kleshenger	Coat hanger	2	Hypernymy
Lo+Lo	Verden	Kart	Map	5	Synonymy
		Atlas	Atlas	2	synonymy

Appendix VIII: I1's responses to the picture naming test

IMG+PND	Target	Response	Translation	Correct	RT	Notes
Hi+Hi	Byste	Statue	Statue	no	*9456*	Synonymy
Hi+Hi	Gave	Presang	Present	no	*3235*	Synonymy
Hi+Hi	Gjerde	Gjerde	Fence	yes	1349	
Hi+Hi	Hage	Dyrket mark	Cropland	no	*14301*	Synonymy
Hi+Hi	Hode	Hode	Head	yes	10083	
Hi+Hi	Høne	/^{1}øne/	Hen	yes	2691	Phonological deviant
Hi+Hi	Jakke	Anorakk	Anorak	no	*5259*	Hyponymy
Hi+Hi	Løve	Tiger	Tiger	no	*1770*	Synonymy
Hi+Hi	Mage	Mave	Stomach	yes	10023	
Hi+Hi	Nese	Nese	nose	yes	14374	
Hi+Hi	Pinne	Kjepp	Stick	no	*12397*	Synonymy
Hi+Hi	Suppe	Melk	Milk	no	*10482*	Synonymy
Hi+Hi	Tåke	Grått	Gray	no	*6967*	Synonymy
Hi+Hi	Teppe	Teppe	Blanket	yes	5333	
Hi+Hi	Veske	Veske	Bag	yes	1540	
Hi+Lo	Åker	Åker	Field	yes	2460	
Hi+Lo	Ballong	/ʋaɭɔŋ/	Balloon	yes	3950	phonological deviant
Hi+Lo	Dame	Kvinne	Woman	no	*2839*	Synonymy
Hi+Lo	Ekorn	Pusekatt	Kitty	no	*1702*	Synonymy
Hi+Lo	Elev	Kvinne	Woman	no	*5074*	Perseveration
Hi+Lo	Flue	/flye/	Fly	no	3500	phonological deviant
Hi+Lo	Kanin	Kanin	Rabbit	yes	2844	
Hi+Lo	Melon	Banan	Banana	no	*2562*	Synonymy
Hi+Lo	Nøkkel	Nøkkel	Key	yes	2004	
Hi+Lo	Orgel	Orgel	Organ	yes	1963	
Hi+Lo	Rosin	Pastill	Lozenge	no	*2219*	Synonymy
Hi+Lo	Søppel	Søppelkasse	Garbage can	yes	1601	
Hi+Lo	Sukker	Kaffekjele	Coffee pot	no	*1479*	Association
Hi+Lo	Tiger	Tiger	Tiger	yes	1449	
Hi+Lo	Vaffel	Kake	Cake	no	*2836*	Hyponymy
Lo+Hi	Fare	Stoppskilt	Stop sign	no	*1854*	Picture related
Lo+Hi	Hvete	Blomst	Flower	no	*3247*	Synonymy
Lo+Hi	Kjerne	Midt	Middle	no	*1736*	Synonymy
Lo+Hi	Lærer	Kvinne	Woman	no	*1194*	perseveration
Lo+Hi	Leder	Veiviser	Guide / location finder	no	*7079*	Synonymy

Lo+Hi	Liste	Liste	List	yes	5670	
Lo+Hi	Lykke	Glede	Happiness	no	*3208*	Synynomy
Lo+Hi	Nåde	Bønn	Prayer	no	*9752*	Synynomy
Lo+Hi	Penger	Penger	Money	yes	1677	
Lo+Hi	Side	Side	Page	yes	6678	
Lo+Hi	Sinne	Sinna	Angry	yes	4219	
Lo+Hi	Sommer	Sol	Sun	no	3968	Synynomy
Lo+Hi	Tanke	Tenker	Thinking	yes	*2762*	
Lo+Hi	Unge	Mann	Man	no	*1363*	Perseveration
Lo+Hi	Vante	Hansker	Gloves	no	1406	Synynomy
Lo+Lo	Avskjed	Vinke	Wave	no	*12494*	Synynomy
Lo+Lo	Bilde	Bilde	Picture	yes	1702	
Lo+Lo	Debatt	Spørreprogram	Quiz show	no	*10655*	Synynomy
Lo+Lo	Fortau	Fortau	Pavement	yes	18644	
Lo+Lo	Gartner	Mann	Man	no	*2321*	Perseveration
Lo+Lo	Helgen	Vismann	Wise man	no	*2378*	Synynomy
Lo+Lo	Idé	Kvinne	Woman	no	*2219*	Perseveration
Lo+Lo	Kjemi	kjemien /ʃemiṇ/	The chemistry	yes	10419	phonological deviant
Lo+Lo	Plante	Blomster	Flowers	no	*1425*	semantic error
Lo+Lo	Protest					No answer
Lo+Lo	Retning	Skilt	Sign	no	*8277*	Synynomy
Lo+Lo	Sirup	kaffe	Coffee	no	*1621*	Synynomy
Lo+Lo	Spørsmål	Spørsmålstegn	Questionmark	yes	1571	
Lo+Lo	Stativ	/si:v/	Rack	no	9441	Phonological deviant
Lo+Lo	Verden	Atlas	Atlas	no	*1963*	synonymy

Appendix IX: I2's responses to the picture naming test

IMG+PND	Target	Response	Translation	Correct	RT	Notes
Hi+Hi	Byste	Hode	head	no	*24038*	Synonymy
Hi+Hi	Gave	gi bort	give away	no	*12460*	Synonymy
Hi+Hi	Gjerde	Gjerde	fence	yes	42757	
Hi+Hi	Hage	Kjøkkenhave	kitchen garden	no	*28517*	Hyponymy
Hi+Hi	Hode	Hår	hair	no	*2981*	Focus
Hi+Hi	Høne	Høne	hen	yes	2692	
Hi+Hi	Jakke	Frakk	coat	no	*12806*	Hyponymy
Hi+Hi	Løve	Løve	lion	yes	8264	
Hi+Hi	Mage	Mave	stomach	yes	4553	
Hi+Hi	Nese	Ansikt	face	no	*15083*	Focus
Hi+Hi	Pinne	Stokk	stick	no	*2938*	Synonymy
Hi+Hi	Suppe	Saus	sauce	no	*21954*	Synonymy
Hi+Hi	Tåke	Tåke	mist	yes	19204	
Hi+Hi	Teppe	Fat	plate	no	12315	Synonymy
Hi+Hi	Veske	Veske	bag	yes	7276	
Hi+Lo	Åker	Plante	plant	no	*12846*	Focus
Hi+Lo	Ballong	Moro	fun	no	13403	Synonymy
Hi+Lo	Dame	Dame	woman	yes	13172	
Hi+Lo	Ekorn	Ekorn	squirrel	yes	7270	
Hi+Lo	Elev	Lærer	teacher	no	*5548*	Synonymy
Hi+Lo	Flue	Fugl	bird	no	27508	Synonymy
Hi+Lo	Kanin	Ekorn	squirrel	no	*6668*	Synonymy
Hi+Lo	Melon	Ost	cheese	no	*14542*	Synonymy
Hi+Lo	Nøkkel	Nøkkel	key	yes	13305	
Hi+Lo	Orgel	Orgel	organ	yes	2297	
Hi+Lo	Rosin					No answer
Hi+Lo	Søppel	Søppel	garbage	yes	2198	
Hi+Lo	Sukker	Sukker	sugar	yes	7034	
Hi+Lo	Tiger	Løve	lion	no	5487	Synonymy
Hi+Lo	Vaffel	Vaffel	wafle	yes	49324	
Lo+Hi	Fare	Oppmerksom	cautious	no	*8606*	Synonymy
Lo+Hi	Hvete	Fjær	feather	no	*30089*	Picture related
Lo+Hi	Kjerne	Del	part	no	*15032*	Synonymy
Lo+Hi	Lærer	Frøken	Miss	no	*5952*	Synonymy
Lo+Hi	Leder	Figur	figure	no	*4451*	Hyperonymy
Lo+Hi	Liste	Program	programme	no	*14019*	Focus

Lo+Hi	Lykke	Fornøyd	content	no	*4225*	Synonymy
Lo+Hi	Nåde	Be	pray	no	*20653*	Synonymy
Lo+Hi	Penger	Penger	money	yes	2516	
Lo+Hi	Side	Blad	page/leaf	no	*5363*	Synonymy
Lo+Hi	Sinne	Irritert	annoyed	no	*5617*	Synonymy
Lo+Hi	Sommer	Fugl	bird	no	*3588*	Focus
Lo+Hi	Tanke	Usikker	insecure	no	*14234*	Picture related
Lo+Hi	Unge	Mann	man	no	*4524*	Synonymy
Lo+Hi	Vante	Hansker	gloves	no	31003	Synonymy
Lo+Lo	Avskjed	Hilse	greet	no	*11722*	Synonymy
Lo+Lo	Bilde	Marka	the forest	no	*11547*	Focus
Lo+Lo	Debatt	Samtale	conversatio n	no	*46669*	Synonymy
Lo+Lo	Fortau	Vei	road	no	*32659*	Synonymy
Lo+Lo	Gartner	Gartner	gardener	yes	7549	
Lo+Lo	Helgen	Prest	priest	no	*9464*	Synonymy
Lo+Lo	Idé	Idé	idea	yes	3532	
Lo+Lo	Kjemi	Mekanikk	mechanics	no	*14422*	Synonymy
Lo+Lo	Plante	Jord	earth	no	*26007*	Focus
Lo+Lo	Protest	Protestere	(to) protest	yes	21148	
Lo+Lo	Retning	Retning	direction	yes	16114	
Lo+Lo	Sirup	Kaffe	coffee	no	*12084*	Synonymy
Lo+Lo	Spørsmål	Spørsmål	question	yes	7887	
Lo+Lo	Stativ	Henger	hanger	no	*9270*	Synonymy
Lo+Lo	Verden	Verdenshistorie n	world history	no	*7276*	Synonymy

Appendix X: I3's responses to the picture naming test

IMG+PND	Target	Response	Translation	Correct	RT	Notes
Hi+Hi	byste	statue		no	*2019*	Synonymy
Hi+Hi	gave	presang	present	no	*2004*	Synonymy
Hi+Hi	gjerde	rekkverk	railing	no	*4759*	Synonymy
Hi+Hi	hage	blomster	flowers	no	*39482*	Focus
Hi+Hi	hode	hode	head	yes	4354	
Hi+Hi	høne	høne	hen	yes	8796	
Hi+Hi	jakke	jakke	jacket	yes	*2356*	
Hi+Hi	løve	løve	lion	yes	3561	
Hi+Hi	mage	slank	skinny	no	*4760*	Focus
Hi+Hi	nese	nese	nose	yes	1714	
Hi+Hi	pinne	stokk	stick	no	*2240*	Synonymy
Hi+Hi	suppe	ertestuen	pea stew	no	*9858*	Hyperonymy
Hi+Hi	tåke	skyer	clouds	no	*2841*	Synonymy
Hi+Hi	teppe	teppe	carpet	yes	2475	
Hi+Hi	veske	koffert	suitcase	no	*5232*	Synonymy
Hi+Lo	åker	åker	field	yes	1794	
Hi+Lo	ballong	ballong	balloon	yes	4653	
Hi+Lo	dame	kvinne	woman	no	*3940*	
Hi+Lo	ekorn	ekorn	squirrel	yes	9602	
Hi+Lo	elev	matematikk	mathemathics	no	*4240*	Focus
Hi+Lo	flue	flue	fly	yes	2581	
Hi+Lo	kanin	kanin	rabbit	yes	1992	
Hi+Lo	melon	vannmelon	water melon	no	*15577*	Hyperonymy
Hi+Lo	nøkkel	nøkkel	key	yes	1442	
Hi+Lo	orgel	orgel	organ	yes	3204	
Hi+Lo	rosin	rosiner	raisins	yes	5820	
Hi+Lo	søppel	søppelkasse	garbage can	yes	*1766*	
Hi+Lo	sukker	ʃukr̩	sugar	no	*21318*	Phonological deviant
Hi+Lo	tiger	tiger	tiger	yes	2475	
Hi+Lo	vaffel	baflerr	wafle	no	*6570*	phonological deviant
Lo+Hi	fare	skilt	sign	no	*2114*	Synonymy
Lo+Hi	hvete	havre	oatmeal	no	*15617*	Synonymy
Lo+Hi	kjerne					no answer
Lo+Hi	lærer	lærerinne	teacher (female)	yes	*18898*	
Lo+Hi	leder	veiviser	guide / location finder	no	*7798*	Synonymy
Lo+Hi	liste	sjekke ut	check off	no	*6593*	Focus
Lo+Hi	lykke	Jippi!	yippee!	no	*1886*	Synonymy

Lo+Hi	nåde	hånd	hand	no	*19736*	Focus
Lo+Hi	penger	penger	money	yes	1613	
Lo+Hi	side	rive	tear	no	*4784*	Focus
Lo+Hi	sinne	sinne	anger	yes	2333	
Lo+Hi	sommer	sol	sun	no	*17867*	Synonymy
Lo+Hi	tanke	tanker	thoughts	yes	4291	
Lo+Hi	unge	blå	blue	no	*11644*	Focus
Lo+Hi	vante	hansker	gloves	no	2499	Synonymy
Lo+Lo	avskjed	farvel	farewell	no	*3724*	Synonymy
Lo+Lo	bilde	bilde	picture	yes	6434	
Lo+Lo	debatt	tale	speech	no	*26287*	Synonymy
Lo+Lo	fortau					no answer
Lo+Lo	gartner	ʋɔnsteɾ	flowers	no	8592	Focus
Lo+Lo	helgen	prest	priest	no	*2744*	Synonymy
Lo+Lo	idé	idé	idea	yes	2324	
Lo+Lo	kjemi	ʃemi	chemistry	yes	*8410*	phonological deviant
Lo+Lo	plante	vase		no	*2538*	focus
Lo+Lo	protest	pɾustest	protest	no	21998	phonological deviant
Lo+Lo	retning	stige	ladder	no	9442	focus
Lo+Lo	sirup	kaffe	coffee	no	*1565*	Synonymy
Lo+Lo	spørsmål	spørsmål	question	yes	2061	
Lo+Lo	stativ					no answer
Lo+Lo	verden	kart	map	no	*1713*	Synonymy