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Priming effects in early readers

A quantitative study of children's response times in visual lexical decision-making in their first and second language

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Abstract

This thesis investigates the effects of various conditions of open priming on children in a series of lexical decision tasks in their first and second language. The primes are related through meaning and/or form to the target words in the experiments. The five conditions used are same word priming, meaning-related, shared first syllable, shared last syllable or unrelated. In addition, the experiment consists of 50% pseudo-words.

There are two experiments which both consist of two parts. The first experiment is designed to investigate how priming affects children in their first language, Norwegian. The second experiment is designed to investigate how priming affects children in their second language, English. Each experiment consists of two equal parts, one part where the target word is primed and one part where the target word is not primed. The unprimed responses provide information used to calculate a predicted response time. This is used to ensure that the results are not skewed by the fact that children read at different speeds.

The results show that children benefit from priming, especially in L2 where they appear to rely on orthographic similarity between the words. In L2 response times were significantly reduced when primed with the same or a form-related word. In L1, the results for priming were weaker, and only one type of form-related priming significantly reduced response times in the model that takes expected response times based on baseline responses into account. This supports mainly Seidenberg's (2005, 2012) PDP model, especially in L2. There are few indications in the data that meaning-related primes has an excitatory effect on lexical decision making tasks in 12-year-old Norwegian children as suggested by Levelt (1989, 2001).

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Contents

List of tables

List of figures

1 Introduction

What makes a word a meaningful word and how do people distinguish meaningful words from nonsense words? New words are created frequently, and some are coined with a certain meaning whilst others are not. The quote below, which is from an early episode of the sitcom *Friends* (Warner Brothers, 1995) where the group discusses Chandler's third nipple, illustrates that it is not always easy to decide:

Monica: Oh, it's not big. Not at all. You know, kind of the same as, I don't know, a third nipple!

Phoebe: [*Gasps*] You have a third nipple?

Chandler: [*to Monica*] You bitch!

Ross: Whip it out! Whip it out!

Chandler: No. C'mon! There's nothing to see. It's a tiny bump. It's totally useless.

Rachel: As opposed to your other multi-functional nipples?

Joey: I can't believe you! You told me it was a nubbin!

Ross: Joey, what did you think a nubbin was?

Joey: I don't know. You see something, you hear a word. I thought that was it. Let me see it again!

Ross: Yes! Show us your nubbin!

A literate adult is supposed to be able to decide if a word is a real word or a made up word in an instant, otherwise he or she is likely to be ridiculed like Joey is in the quote above. Now, nubbin as a noun does appear in the *Oxford English Dictionary* (OED) with three different meanings; none of which refer to a third nipple. However, the conversation in the quote indicates that Chandler just made up a word rather than to call it a third nipple, and that Joey is the stupid one because he is not aware of the "fact" that it is not intended to be a word. Yet even with a quarter of a million distinct English words, as estimated by the *Oxford Dictionaries* (n.d.), we are expected to be able to distinguish at the spot between actual words and pseudo-words, but how do we actually do that? Equally interesting is the question: how do we become able to do this? In order to attempt to answer the latter, this thesis aims to shed light on some of the early processes of visual word recognition in children in their first and second language.

1.1 Introduction to the research topic

One core interest of psycholinguistics is how the mental lexicon is organized and how people are able to make sense of words as fast as they do. Considering the number of words we know and the speed at which we process and produce them, it is clear that there has to be a system behind the organization of words in our minds. From a teaching point of view, the purpose of studying how the brain copes with words is not only to satisfy researcher's curiosity. Furthermore, this research is an important contribution to theories on literacy instruction. Like Seidenberg says:

> Reading failures arise from multiple causes. My goal has been to suggest that this serious societal issue can further benefit from the kinds of research that we conduct as scientists who study reading and language.
>
> (Seidenberg, 2013: 355)

However, an important question is if this system is fully in place from the beginning of life or if it develops throughout our lives. One way of studying this is by examining how quickly we process words and which other factors affect the speed of processing. This can be done using computer software which measures the reaction time. Through carefully designed experiments, using appropriate words as stimuli, the reaction times may indicate how the words affect each other, and thereby suggest a possible connection, or lack of so, between the different words.

This thesis is an investigation of children's reaction time in visual lexical decision-making tasks in their first (L1) and second (L2) language. This is studied by using a computerized priming test to measure response times (RT). The software registers how much time the participant needs from the point in time when he or she sees a target word on screen until he or she accepts or dismisses the word. Half the words are pseudo-words while the rest are real words and the participants are required to classify words as either real words or pseudo-words. Showing a distracter word, or a prime, for a short period just before the target word may have an effect on the RT. The primes are categorized into different conditions, which may provide information about how words are stored in the participants' brains. The experiment is done twice, once in L1 and once in L2. The aim is to elucidate differences in the process of visual word recognition in L1 and L2 in 12 year old children at two Norwegian elementary schools.

1.1.1 Theoretical framework

Several models have been proposed since the 1950s in the search for an understanding of how the words, the brain, the eyes, the ears and the mouth are connected. These models have been based on different types of research into topics such as errors in speech, naming tasks and lexical decision tasks.

A key focus within the study of language is the effect of priming on language processing and production. Priming is about how exposure to one word may affect how another word is perceived, and it has been used in conjunction with lexical decision tasks to show that relations between lexical items have an effect on how quickly they are accessed (Meyer and Schvaneveldt, 1971:227).

Research by Willem Levelt (2001) argues that priming influences the articulation process of spoken words. He formulates a theory of how speech is produced from a lexical point of view rather than a biological one. Based on research by several other scientists, his paper discusses how we choose a word before we even know which word is the most appropriate one. Support for this hypothesis is found in Meyer (1990, 1991) and is based on an experiment with a "display target word – display probe words – measure spoken target word" design. The main finding is that shared first syllables speed up the articulation of the word, while shared last syllables significantly slow down the articulation.

Several other experiments of this kind have linked visual images to written or spoken words, using both monolingual and bilingual participants. Stremme (2015) uses both English and Norwegian words in a cross-linguistic experiment. She found that beginners had the same effect of priming between languages as bilingual participants; however, their responses were generally slower. In comparison, this proposed thesis suggests that data from children, who are L2 novices, but also not fully trained in their L1, may differ from the previous experiments. Seidenberg (2012) argues within the framework of the PDP model that:

> Because they are systems that learn, the models provide a unified account of acquisition and skilled performance. The same principle governs both; children and adults represent different points on the developmental continuum represented by states of the model over training time.
>
> Seidenberg (2012: 194)

The results will mainly be interpreted independently for each language. The data also open the possibility to examine the bilingual aspect by comparing the results for both languages for the same group of children. However, in this thesis the focus is on how children process words in L1 and L2. Individual interpretations of L1 and L2 will therefore shed light on the mental lexicons at a certain stage in their development. The jury is still out on the question of how and where multiple languages are stored (Durgunoglu and Roediger, 1987: 377). This will not be examined and neither will the relationship between the languages for individual participants as the hypotheses pertain to effect of priming in each of the languages, rather than to cross-linguistic processes. It is important to bear in mind that Norwegian is the native language of the participants in this study, whilst they are novice users of English, which they are taught as a foreign language within a Norwegian linguistic context.

1.2 Research hypothesis

One expectation is that word-to-word priming will have an effect on children. This would indicate that children's mental lexicons are structured such that words are related in either meaning or form, as shown in earlier studies on adults (Meyer and Schvaneveldt, 1971). Based on this, the following hypotheses may be formulated:

H_0: Word-to-word priming of related words does not affect RTs in children

H_1: Word-to-word priming of related words does affect RTs in children

Another expectation is that, if there is a priming effect, it will be stronger in L1 than L2 because children's L1 mental lexicons are further developed than their L2 mental lexicons. Based on this, the following hypotheses may be formulated:

H_0: The priming effect is the same in L1 and L2.

H_2: The priming effect is different in L1 and L2.

A better understanding of the underlying processes of visual word recognition of known words will benefit research on how we access the mental lexicon and how we produce and reproduce language.

1.3 Organization of the text

Chapter two reviews several theories which all have had a great influence on research on lexical access as well as theories regarding first and second literacy acquisition from a teaching point of view. Chapter three is an extensive outline of the methodology used in this thesis. Chapter four presents the findings from the experiments. Chapter five discusses the findings from chapter four in light of the theories which were reviewed in chapter two. Chapter six is the conclusion. In addition, some background information and tables are included in the appendices for transparency purposes.

2 Literature review

There are several theories regarding our mental lexicon, in other words; how words are stored in the human brain. Understanding how we access the mental lexicon is important because it provides insight into how we produce speech and how we read. This chapter will review various theories relevant to answering the research questions outlined in the introduction: Does word-to-word priming have an effect on children in their first and second language?

The first part deals with the main theories regarding how words are processed while we read, as well as lexical access in general. The second part is a discussion of the methods used to investigate the mental lexicon. This includes both how priming may contribute to our understanding of the mental lexicon, and the question of whether to use lexical decision tasks or naming tasks to study this. The remaining three parts deal with language and children in particular; how they learn the meaning of words in their first language, how they acquire a second/foreign language and finally some approaches to reading strategies building on the theories about lexical access.

In light of all the various terminology used in the literature on the topic of the mental lexicon, it is important to establish what is reading is. Barton (2007: 18) argues that reading has more than one definition, rather it is a scale which goes from mechanical utterings to interpretation of text. According to Seidenberg (2012: 190), there are four processes related to the use of words: "*Reading* is the process of computing a meaning (or pronunciation) from print. *Spelling* is computing from sound or meaning to print. *Listening:* phonology to meaning. *Production:* meaning to phonology." Reading is by this definition seeing a written word and being able to extract meaning from it. Due to the notion of computing meaning, visual word recognition alone is therefore not synonymous with reading, and the two terms should not be used interchangeably. However, visual word recognition is clearly an important aspect of reading and thereby affects the overall reading process.

2.1 Various theories and models concerned with the words in the mind

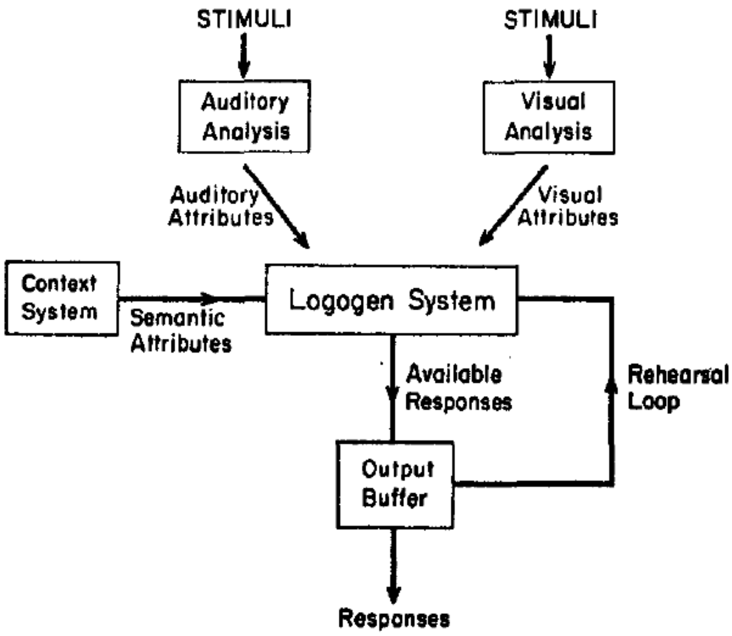
When researchers first became curious about how words are connected in our minds, they initially recorded errors in speech (Aitchison, 2012:21). An important idea is that by looking at what goes wrong, we get an understanding of how the whole system works due to the assumption that words or sounds that get mixed up are somehow linked. Based on this rationale, researchers investigated which sounds we are most likely to mix up when we speak. For instance, in what is commonly known as a slip of the tongue, we might say *par cark* when we intended to say *car park*, because we assembled the sounds incorrectly (Aitchison, 2012:21, Dell, 1986: 284). Another such error is when we select the wrong word: "For example, "Lizst's second Hungarian *restaurant*" instead of "*rhapsody*"…" (Dell et al. 1999: 517). Dell et al. (1999) argues that the word used incorrectly may be related to the correct word either in meaning, syntax or phonologically. Later, researchers developed new methods to backtrack the process of how speech is produced. The following sections will outline some of the most influential models in this literature.

Dell (1986: 283) claims that "… [spreading activation theories and connectionist models] are, in many ways, starting to form a theoretical paradigm in cognitive psychology". Prior to these theories, there was the Logogen Model by Morton as well as Forster's search model, both of which are briefly discussed in Warren (2013: 144-145). Both these early models, as well as their more recent and improved versions, have contributed strongly to the understanding of reading. Furthermore, the criticisms which have been raised against them have added to the models and the emerging theories on lexical access. These issues will be discussed separately in chapter 2.2.

2.1.1 The Logogen Model

Morton (1969: 165) argues that: "The logogen is a device which accepts information from the sensory analysis mechanisms concerning the properties of linguistic stimuli and from context-producing mechanisms". Figure 2.1 below illustrates how the Logogen System functions as a core into which all other information is fed. Figure 2.1 shows how the information input is shared between three distinct types of stimuli: semantic, auditory and visual. The idea is that when these three types of stimuli are fed into a Logogen System, they will produce an output in the form of a word. However, according to Figure 2.1, the model allows for feedback into the logogen after processing in the output buffer before an actual response is produced; this is the rehearsal loop.

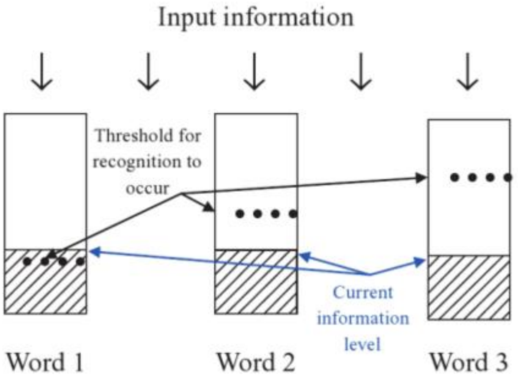
Figure 2.1 Morton's Logogen Model



Source: Morton (1969: 166)

An important aspect to note of the Logogen Model is that the model also recognizes that there is a threshold level that must be reached before a response is made available. This threshold is unique for each word as Figure 2.2 shows.

Figure 2.2 Logogen as containers



Source: Warren (2013: 144)

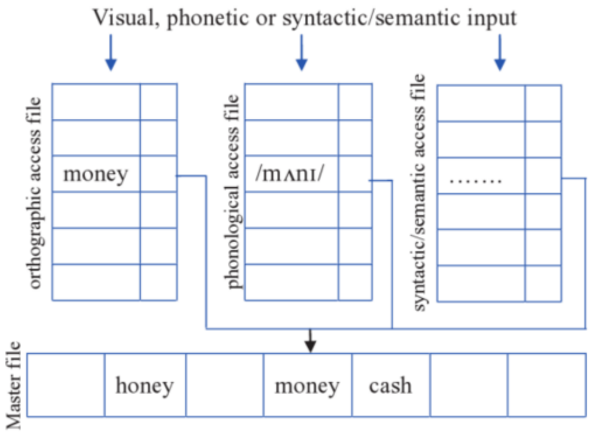
Morton (1969: 168) claims that this is how the Logogen model can handle the frequency of occurrence of words which demonstrated an effect in a study by Brown and Rubestein (1961, cited in Morton 1969: 168). Regardless, there has to be sufficient input from the three categories of information to produce an output. The stimuli may enter the system either through the auditory route as speech or the visual route as printed text. Morton (1969: 166) emphasizes that because the stimuli is introduced to the system at a high speed, either as continuous speech or during reading, the effect does not last for long. Morton suggests that within a second the input to the Logogen System is no longer useful, because the containers which are shown in Figure 2.2 are returned to their original values. Figure 2.2 further illustrates that there is no contact between the words; the input is strictly external.

Warren (2013: 144) argues that this model cannot take into account how words may interfere with each other in form or meaning. Furthermore, an aspect that might affect the threshold level is repeated exposure, which one might see from a more frequent exposure to a high frequency word. However, assuming that the effect is passing at high speed and the threshold is restored at a resting level, how or when does the cumulative effect of high frequency words occur? These two arguments are contradictory as either each exposure must be considered a one-off which does not affect the threshold level, or each exposure will leave some residue and have some kind of cumulative effect which may cause the threshold level to be adjusted.

2.1.2 The Serial Search Model

Forster's autonomous search model is an example of a serial search model. A serial search model, unlike the Logogen model, searches item by item until it finds a match (Warren, 2013: 145). The model, much like the Logogen model, has three types of input; visual, phonetic and syntactic or semantic (Warren, 2013: 145). As Figure 2.3 below shows, the three different inputs are each processed in the relevant access file where words are stored in separate bins according to frequency, initial letter or other orthographic features.

Figure 2.3 Forster's serial search model



Source: Warren (2013: 145)

Coltheart et al. (1977: 545) dismisses the possibility of a search model as it would simply not be fast enough. In their research, they use a lexical decision task where participants are to distinguish between words and non-words, which in this case were pseudo-homophones. The RT was consistently slower for pseudo-homophones than for real words. They further argue that the only model which would be able to cope with their findings is the logogen model by Morton (1969). Andrews (1989: 802) states that the activation framework suggested by Morton (1969) is the beginning of the interactive activation model which was later developed by McClelland and Rumelhart (1981). Warren (2013: 145) emphasizes that the search models have limitations, especially when it comes to the neighborhood effect which will be discussed in depth in chapter 2.7. The Logogen Model and the Serial Search Model clearly contributed to our understanding of the mental lexicon and lexical access the early stages. The spreading activation theory by Dell (1986), as well as the connectionist model offered by Seidenberg (2005) and the interactive activation model by McClelland and Rumelhart (1981) and Rumelhart and McClelland (1982), all build upon the assumption that there is a mental lexicon in which there is a connection between all the units within it, and that various properties, such as features, letters and words, are stored at different layers.

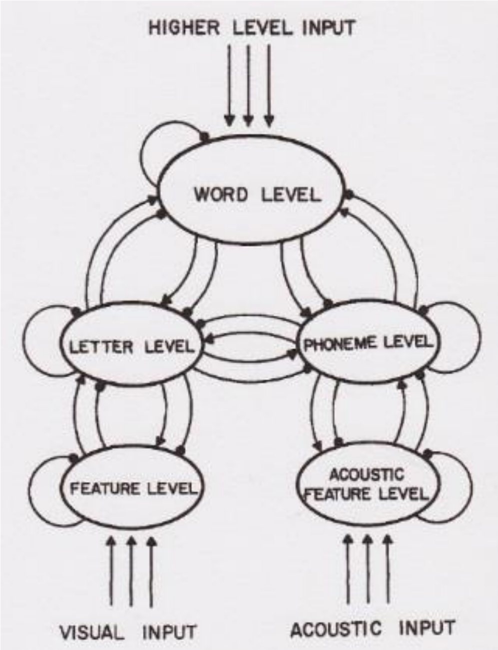
The initial autonomous search model has since been developed further by Murray and Forster and presented as the Rank Hypothesis in Murray and Forster (2004), where they respond to some of the criticism which has been raised against this model over the years. The main criticism is: how can the brain search through so many words in so little time? This is especially true when it comes to declining a word in a lexical decision task (Murray and

Forster, 2004:722). They emphasize the importance of the two stages of the model, where at the first stage all the words are organized in bins and then linked to the second stage where the master file of all words are stored, as shown in Figure 2.3. Furthermore, they discuss the structure and the size of the bins. They argue that the words within a bin are ranked by relative frequency of occurrence. Therefore, it is less important how frequent a word is than how it relates to the other words. They call this the rank hypothesis. As discussed in chapter 2.1.1, the Logogen Model has been criticized for not accommodating word frequency, whereas the search model and the rank hypothesis are to a large extent dependent on frequency. It should be noted that the term frequency refers to how common or uncommon words are to literate native speakers. It is unclear how this model applies to early readers or to second language reading.

2.1.3 Interactive Activation Model

"An interactive activation model of context effects in letter perception" by McClelland and Rumelhart (1981) emphasizes the visual processing of words. It should be noted that the authors are explicitly not referring to the process of reading at this point, merely to the perception of letters. Figure 2.4 below illustrates the flow of the model, which starts with visual and/or acoustic input. This discussion will focus on the visual input. However, regardless of input, the model is based on three assumptions (McClelland and Rumelhart, 1981:377): The first assumption is that "perceptual processing takes place within a system in which there are several levels of processing". As Figure 2.4 shows, there are three main levels: the visual feature level, the letter level and the word level. The arrows between and within the levels illustrate McClelland and Rumelhart's second assumption that "the visual processing occurs at several levels at the same time". Rather than being a strictly forward feed model where processing happens in stages, this model assumes that all levels are activated simultaneously. Additionally, they emphasize that this "is fundamentally an *interactive* process". This view breaks with the assumption that each layer is activated as a result of the activation of the previous layer, as in the two stage approach by Murray and Forster (2004) and the feed forward approach in the Logogen Model by Morton (1969).

Figure 2.4 Interactive activation model



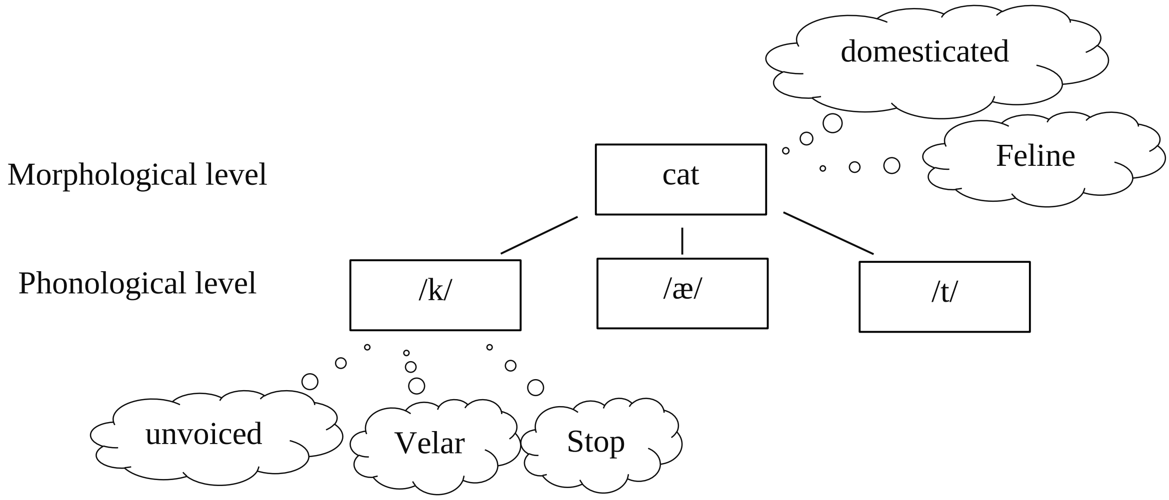
Source: McClelland and Rumelhart (1981: 378)

2.1.4 Dell's linguistic assumptions and the spreading activation theories

Seidenberg (2005:240) argues that: "The intuition that people learn rules and memorize exceptions is powerful and easy to grasp. The idea that the same phenomena can be explained by a multilayer network employing distributed representations and a connectionist learning algorithm is not." Consider a toddler who is learning how to speak, syllable by syllable and word by word until he or she starts to assemble sentences, and it is easy to imagine him or her learning rules and memorizing exceptions. However, this approach does not fully account for the child's ability to later on evolve language by adding to it. If the child, instead of repeating, rehearsing and memorizing, is considered to be building his or her own algorithm, the process appears to be more dynamic.

Gary Dell (1986: 286-287) summarizes how language users know a language on different levels. On the one side, there are four main linguistic levels: the semantic, the syntactic, the phonological and the morphological level. As Figure 2.5 below illustrates, the levels referred to by Dell somewhat correspond to McClelland and Rumelhart's levels in Figure 2.1, although Dell does not specify a model for visual perception as his studies are designed to understand sentence production. Dell argues that speakers have to be aware of these different levels in order to produce and understand language. The thought bubbles in Figure 2.1 are intended to illustrate the generative rules. At each level, there are generative rules which regulate which phonemes, syllables or words may be combined in order to create new utterances. According to Dell, these generative rules come in addition to the lexicon, which he classifies as “nonproductive stored knowledge” (Dell, 1986: 286). In the lexicon, there are conceptual nodes which are connected to the word nodes, and in that way the words are filled with meaning. As the illustration below shows, the node *cat* on the morphological level is connected to the phonemes /k/, /æ/, and /t/ on the phonological level. This means that in the lexicon the node for /k/ is linked to the phonemic features such as unvoiced, velar and stop. Additionally the node *cat* is linked to conceptual features such as *domesticated* and *feline*. In line with this model, the following idea can be deduced: a proficient speaker of English has stored this information in his or her lexicon, but a learner with a different set of phonemic features linked to the letter <c> may either mispronounce the word or he or she will have to actively remember the generative rules in order to produce understandable English speech.

Figure 2.5 An interpretation of Dell's linguistic levels and features



Source: author’s interpretation of Dell (1986)

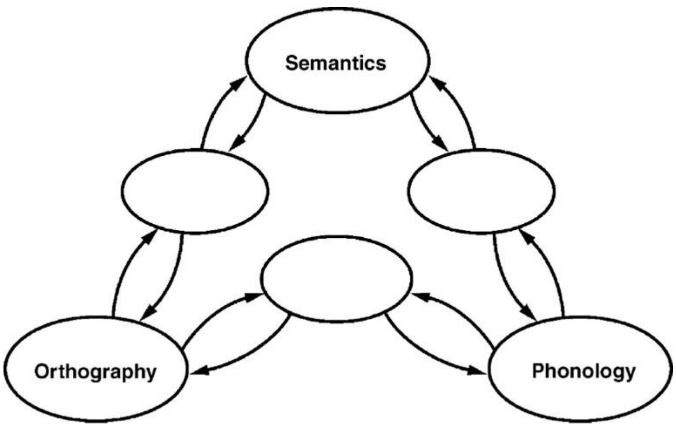
2.1.5 The link between the nodes, the rules for selection and the exceptions

Dell (1986) does not specify the directions of the relations between the various nodes. Rather, he emphasizes the interaction between the generative rules and the lexicon. Dell acknowledges that there is a lexical selection process at each level and that there are certain rules. The following paragraph will discuss two approaches to the activation variable.

With such a massive amount of information distributed in a network of nodes which connects across levels, a main question is how the nodes are linked and activated. Dell (1986: 287-288) claims that other models based upon the same type of network assume that the activation is a binary variable, which is either on or off. His theory, on the other hand, assumes that it is a real variable and that there is a level of activation given by the node j at time t, denoted A(*j*,*t*). This means that not all nodes are equally activated at all times. However, all nodes with some level of activation will activate its connections at a given time. This theory assumes that the activation level cannot be negative and therefore the process cannot be inhibitory.

Seidenberg (2005) presents a connectionist model of word reading, rather than of speech production as in Dell (1986). In this model, which is known as the Parallel Distributed Process and was developed with McClelland in 1989, Seidenberg argues that Dell's model requires a knowledge based on too many rules and exceptions, and Seidenberg introduces instead the notion of 'quasiregularity'. According to Seidenberg, there are degrees of consistency which the emergent reader simply learns to deal with. However, he also suggests that these irregularities appear both in spelling and in morphology (Seidenberg, 2005: 238-239). The network of information is illustrated in a simplified illustration in Figure 2.6.

Figure 2.6 Triangle model by Seidenberg and McClelland



Source: Seidenberg (2005: 239)

The figure shows how each layer or feature is represented, and how all are connected directly to some of the others, but not to all. This model applies to the connectionist theoretical approach to word reading and illustrates how the various nodes interact with each other.

The idea is that there is a flow of activation and that each connection has a certain weight, much like the real variable (real as opposed to a binary variable) suggested by Dell (1986: 287), and that this is a 'feedforward network' (Seidenberg, 2005: 239). The connectionist model proposed by Seidenberg (2005: 239) does not require a memorized lexicon of words. Nevertheless, even if a novice reader does not memorize words, he or she learns how to adjust the weights of the activation connection. The weight of the activation is related to the discussion of the purpose of the activation. Can the activation only have an excitatory effect, or may this effect also be inhibitory? McClelland and Rumelhart (1981: 387) argue that the inhibitory effect is necessarily strong at the word level because of multiple activations on both feature and letter level. Letter level activation will activate all the words which share more than one letter with the target word, and it is therefore necessary to reject irrelevant words by introducing an inhibitory effect on a word-to-word level.

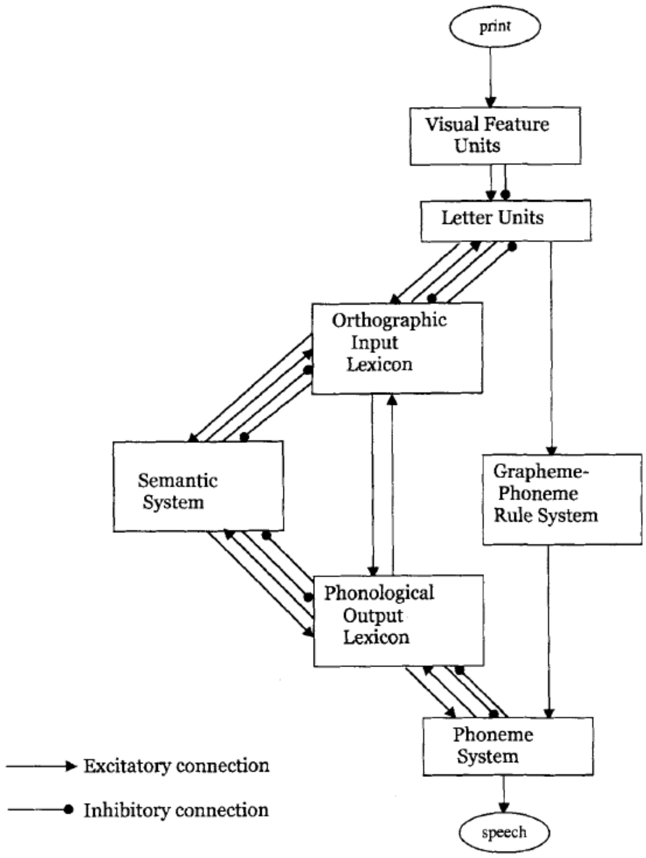
2.1.6 The Dual-Route Cascade

The Dual-Route Cascade (DRC) or the Dual-Route approach is a computational model developed by Coltheart et al. (2001), who emphasize both the orthographic information provided, as well as the phonological information implied by the word. This is a computational model, which is a computer programmed model rather than a model based on experiments. The model is fed various input and the output is therefore the result of the input as the model learns how to produce speech. It is presented as the new and improved version of the Interactive Activation model (Coltheart et al. 2001: 206).

A key aspect to this model is that the developers of the model claim to be "adherents of the Old Cognitivism" (Coltheart et al. 2001: 205). Therefore they are less interested in how the brain learns and builds new connections like the PDP model described in the above section. Coltheart et al. (2001) are interested in how the brain is set up from the beginning. The following outline of the model is based entirely on Coltheart et al. (2012). Figure 2.7 shows the architecture of the dual-route cascade model of visual word recognition and reading aloud.

There are three routes in this model: the lexical semantic route, the lexical non-semantic and the grapheme-phoneme correspondence route. There are several layers in each route and these layers interact with each other. The interaction consists of either speed up or slow down the activation of other units in the route. As this model is only concerned with how visual word recognition is processed and converted to speech, there is no reference to meaning.

Figure 2.7 Dual Route Cascade



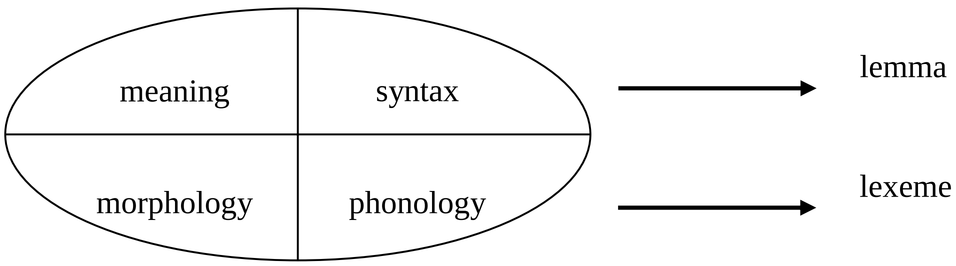
Source: Coltheart et al. (2001: 214)

The excitatory and inhibitory effects between the layers have been programmed into the model in order to simulate reading aloud. This made it possible to investigate phenomena previously studied in humans by other researchers. To mention a few, they find that there is a difference between accepting and declining a word as YES answers are faster, there is a difference between high-frequency and low-frequency words as high-frequency words are accepted faster and it takes longer to decline a pseudo-homophone (c.f. Coltheart et al. 2001: 228).

2.1.7 Levelt and WEAVER++

Willem Levelt (1989, 2001) proposes a theory of lexical access from the perspective of speech production similarly to Dell (1986). “A speaker’s mental lexicon is a repository of declarative knowledge about the words of his language”, according to Levelt (1989: 182). This definition of the mental lexicon more or less overlaps with the one presented by Dell (1986), as previously outlined in section 2.1.4. Levelt (1989) shares the same linguistic assumptions as Dell (1986) in terms of features, but he proposes a different structure of the mental lexicon. According to Levelt (1989), each item in the mental lexicon consists of four features: meaning, syntax, morphology and phonology. Rather than thinking of them as different layers which may imply a certain hierarchy, Levelt (1989: 182) presents them as four integral parts which together form each entry, as shown in Figure 2.8.

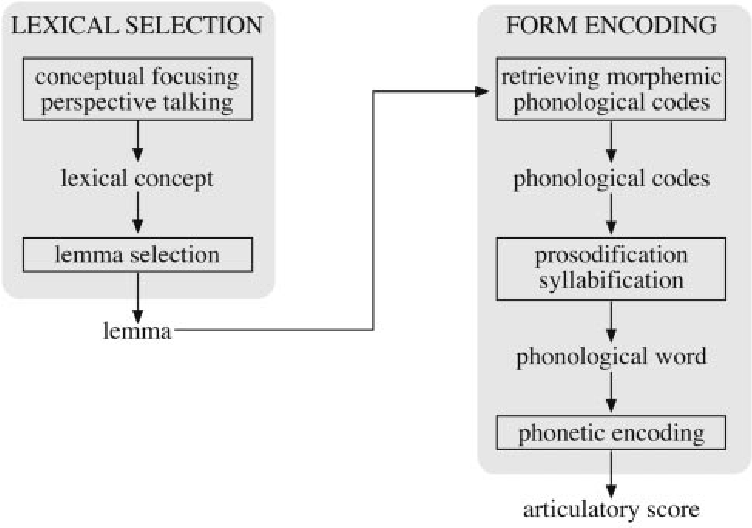
Figure 2.8 Adaptation of Levelt’s structure of a lexical entry



Source: Author’s adaptation of Levelt (1989: 188)

Meaning and syntax are both part of the lemma which is not pronounced or visualized in any way, whereas the lexeme is the word which may be communicated either through print or speech. Whereas the lemma is independent of a language, the lexeme is articulated. However, according to Levelt (1989: 182-182), the lemma also contain syntactic information about the concept. The realization of the syntactic information belonging to the lemma stages does not appear until it reaches the lexeme stage. This process is presented as a two-system architecture, as seen in Figure 2.9.

Figure 2.9 Two-system architecture

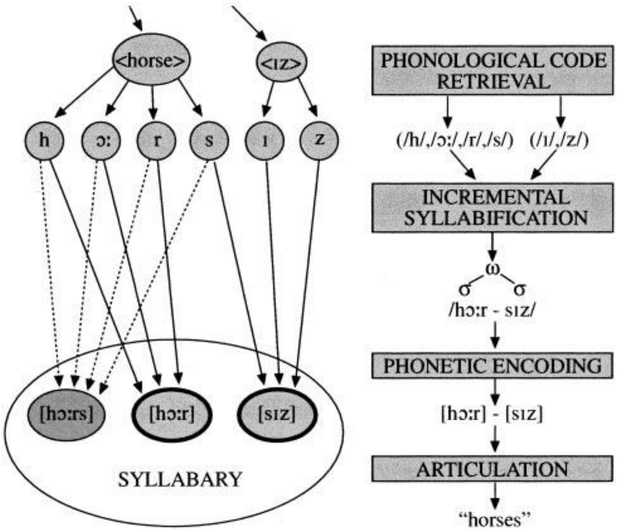


Source: Levelt (2001: 13465)

As Figure 2.9 illustrates, there is one system that is concerned with lexical selection. In this system, the speaker is only concerned with the lexical concept (denoted in capital letters), for example HORSE, as related to, but also opposed to, STALLION and ANIMAL. When an English speaker sees an image of a horse, the selection of the lemma (denoted in italics) *horse* will reflect an appropriate level of detail, the appropriate register, and it will have certain syntactic features attributed to it such as that it is a count noun and whether it is singular or plural. Exactly which syntactic features are attributed to a lemma depends on the active language. For instance, the corresponding lemma in French, *cheval*, will also be marked for gender. However, at this point in the process, the lexical selection has not been encoded for form, i.e. the morpheme have not been selected. This process is initiated by the selection of a lemma. In the form encoding system, the necessary syllables are placed together in order to create a word that reflects the lemma. Therefore, according to Levelt, a speaker does not remember both <horse> and <horses> as single and separate entries. Instead, the lemma *horse* can be encoded for both singular and plural. When the lemma is syntactically encoded for plural, it becomes multi-morphemic in the form encoding stage of speech production. However, in English, in the case of <horse> and <horses>, the syllabification does not correspond with either the orthographic changes from singular to plural or the phonological changes. Orthographically, the only change is an added <s>.

Phonologically /ɪz/ is added after /hɔːs/. Yet, in the syllabification process, the structure of the word changes to /hɔː/ /sɪz/. Figure 2.10 shows the structure of this network.

Figure 2.10 Form encoding network

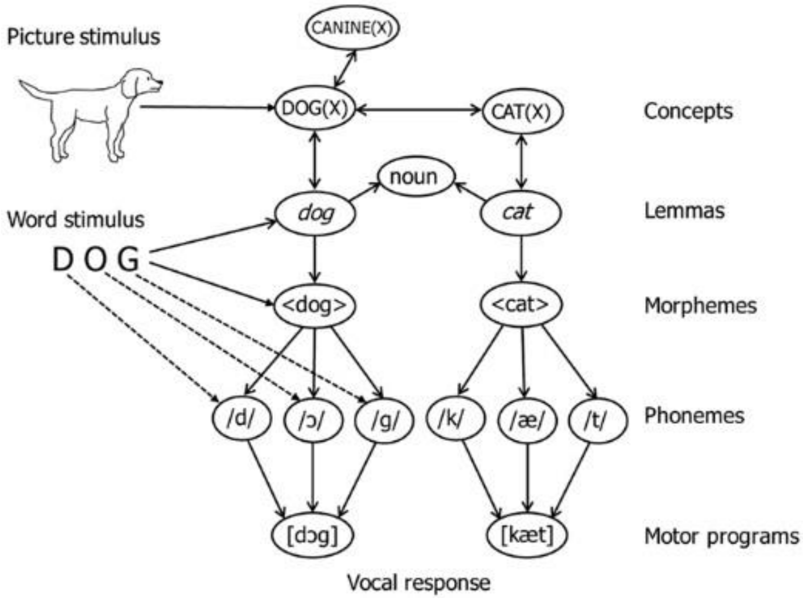


Source: Levelt (2001: 13465)

Roeloefs (1997) introduces a computational model for speech production, with lemma retrieval, called WEAVER++. WEAVER stands for Word-form Encoding by Activation and VERification (Roelofs, 1997: 250). The model builds upon both Dell's model of spreading activation as well as Levelt's idea of syllabary access which Dell's model does not include. Roelofs (2000: 84) emphasizes the importance of a syllabary which he argues solves the problem of phonetic encoding.

"Words are not planned by a central agent that overlooks the whole process but by a team of procedures that work in parallel on small parts of the word, like several spiders making a single web" (Roeloefs, 1997: 250). Figure 2.11 below illustrates how the encoding network is connected.

Figure 2.11 WEAVER++ encoding network



Source: Roelofs and Piai (2011)

Roelofs (2000: 95) argues that "according to WEAVER++, both begin-related (e.g., first syllable) and end-related (e.g., second-syllable) spoken primes yield facilitation, because they will activate segments of the target word in the memory and therefore speed up its encoding". Although priming in itself has an inhibitory effect (Roelofs, 1997: 264), priming will activate a morpheme in a cohort which again will activate other morphemes in the cohort.

2.2 General criticisms of the models

However, a model does not include every feature of what it is intended to modulate. None of models discussed in chapter 2.1 have been able to account for every aspect of what seems obvious or natural related to reading. Frequency, as well as neighborhood size and density, have caused researchers to doubt the validity of models of lexical access. This subsection aims to dig deeper into these two main issues which have been the subject of several studies.

2.2.1 Neighborhood and frequency effects

An orthographic neighborhood is a set of words which “share similar properties” (Warren, 2013: 134), which for written words imply similar spelling patterns. Examples given by Warren (2013: 143) are: “<work>, <ward> and <ford> would all be orthographic neighbors of <word>.” As the examples show, despite the differences between the first three words, each of them only deviates with one letter from <word>, which is why the other three constitute the neighborhood for <word>. Carreiras et al. (1997: 857) define an orthographic neighborhood based on the explanation given by Coltheart et al. (1977):

> An orthographic neighbor is any word that can be mated by changing one letter of the stimulus and preserving letter positions (e.g., lift, list, and pint are neighbors of lint). The index N is typically used to refer to the number of orthographic neighbors of a given word.
>
> (Carreiras et al., 1997: 857)

There are two different aspects to how the idea of an orthographic neighborhood may affect how a person reads a word. The first aspect deals with the neighborhood frequency effect which measures how a low-frequency word is affected by a high-frequency neighbor. Carreiras et al. (1997:857) argue that various studies across several languages have shown that “words with higher frequency neighbors are harder to recognize than words without higher frequency neighbors”. Warren (2013: 143) states that: “A general finding is that responses to low-frequency words, but not those to high-frequency words, are affected by neighborhood size”. In most orthographic neighborhoods, such as the one for <word>, the words have varying frequency. In the example with <word>, a high frequency word with lower frequency neighbors, <ward> and <ford>, <word> would not be affected by the numbers of neighbors according to Warren’s proposition above. However, a low frequency word such as <dole> with a large number of neighbors, such as[1] <bole>, <mole>, <sole>, <pole>, <dale>, <dome>, and <dolt>, might be affected by having a large orthographic neighborhood. The second aspect deals with the neighborhood density, which refers to the

[1] This list is not exhaustive

size of the neighborhood as some words may have only one neighbor whereas others have many. Carreiras et al. (1997:869) suggest that a large neighborhood may have an inhibitory effect, but conclude that “these different tasks are maximally sensitive to different types of variables” as they use five different methods to investigate the effects of orthographic neighborhoods. They list several projects which have investigated the effect these words have on each other and found the effect to be facilitatory. However, these experiments have been in conjunction with other variables such as the neighborhood-frequency effect (Grainger, 1990; Sears et al., 1995) and neighborhood density controlled for onset and rime[2] consistency (Treiman et al. 1995).

Sally Andrews (1989, 1992) investigates in a series of experiments the effect of frequency and neighborhood on lexical access using both lexical decision tasks and naming tasks. Andrews (1989:812) argues that her findings demonstrate that frequency affects lexical access in lexical decision tasks more than it does in naming tasks. She ascribes these findings to the nature of the lexical decision task. However, in Andrews (1992), she finds that the neighborhood effect and the frequency effect are due to lexical similarity, not to orthographic redundancy. In other words, the letters they share are more important than the letters that set them apart. She argues that this incompatible with the search models, but that it fits in well in the interactive activation model. Furthermore, she discusses the distinction between orthographic neighbors and phonological neighbors, arguing that “Phonological consistency has been demonstrated to influence word-naming performance […], but its effect on lexical decision responses is far less clear” (Andrews, 1992: 249). She further suggests that this is because phonological consistency aids pronunciation more than it aids word recognition.

2.3 Methodological issues

Cattell (1886a, 1886b) investigated how much time a person needs to name an object, with the aim of proving that cerebral operations can be measured. However, he states that the nature of the experiments and their premises are not unproblematic.

[2] Rimes look alike whilst rhymes sound alike. Treiman et al. (1995) focus on the written word.

The conditions of the experiments place the subject in an abnormal condition, especially as to fatigue, attention and practice, and the method has often been such that the times given are too short, because the entire mental process has not been measured, or too long, because some other factor has been included in the time recorded.

(Cattell 1886a: 63)

The nature of experiments is, as Cattell points out, artificial and abnormal. Experiments are ideal for controlling for confounding variables known to influence lexical decision making.. However, they may also become so artificial or biased that they no longer measure what they set out to measure (McLeod, 2012). Regardless, laboratory experiments have been the preferred choice of psycholinguists interested in the mental lexicon due to need to control for confounding variables as well as to be able to measure response times. These requirements are difficult to change, and therefore the researcher must take into account that the experiment cannot be too long or too short in order to avoid fatigue and loss of attention by the participants. At the same time, the experiment must provide a sufficient number of observations in order to provide statistical power in the analyses. Furthermore, the researcher must know what to measure. This will be further discussed in the following chapter in light of the most common experimental tasks used in the study of the mental lexicon.

2.3.1 Lexical Decision Tasks

The two most common experiment tasks in the study of the mental lexicon are lexical decision tasks and naming tasks. Lexical decision making tasks usually involve both real words and non-words and the participant has to decide if the target word is a real word or not (Andrews, 1989: 805, Katz et al. 2011). This method was first used by Meyer and Schvaneveldt (1971). The benefits of later versions of this method is that it completely eliminates any cognitive efforts or physiological efforts related to speech production. Furthermore, it is easy to add controlled interference to the lexical decision task experiment. One such interference might be priming, which will be discussed in chapter 2.3.2.

Naming tasks require the participant to read aloud a printed word (Katz et.al 2011). Is this an alternative technique which is equivalent to the lexical decision task method, or is there more to the two techniques than what meets the eye? Andrews (1989) aims to compare the two techniques and claims, following her comparative investigations on the effect of frequency and neighborhood, that "… frequency effects are magnified in the LDT as a function of processes involved in word/nonword discrimination" (Andrews, 1989:812). Regardless, she argues that lexical decision tasks do reflect the true effect of frequency, while in naming tasks there may be other aspects which influence the RT. Katz et al. (2011) support this claim, arguing that there is more decoding involved in naming tasks than in lexical decision tasks.

2.3.2 Priming

The early lexical decision tasks consisted of measuring the RT between the presentation of the stimulus and the response given by the participant (Meyer and Schvaneveldt, 1971:227). Meyer and Schvaneveldt (1971) further explain how a variation of this experiment may shed light on the meaning relations between words. They suggest that prior to the target word another stimuli is presented for a short period of time. Some of these first words, or primes, are related to the target word while others are less related. By measuring all the different RTs and afterwards analyzing the results to look for patterns, the researcher may reveal how different words affect each other.

The arguments is that the prime word works as a distractor in the process of naming a picture and that this has either a weak inhibitory effect or a strong inhibitory effect on the RT (Finkbeiner and Caramazza, 2006: 790). Other forms of priming are word-to-word priming and cross-modal priming which includes both auditory and visual stimuli. These types of priming are all unmasked priming techniques. This means that all stimuli are visible to the participant. The usual order for the presentation is:

Fixation point - prime - TARGET

Altarriba and Basnight-Brown (2007: 6) discuss Stimulus Onset Asynchrony (SOA) as it varies how long each stimuli is visible to the participant. A very short SOA is 50ms whilst 1000ms is considered extremely long. Usual timeframes are between 100ms to 500ms for the prime. Altarriba and Basnight-Brown (2007) mention issues such as language proficiency and word frequency, but they do not discuss potential challenges related to studying children. This thesis can therefore contribute to the field by expanding priming as a methodological approach also to examine children.

2.4 How children learn meaning of words

As the quote from the episode of Friends in the introduction chapter of this thesis illustrates, a common perception of how children learn the meaning of words is exactly how the scenario plays out between Joey and Chandler: Joey saw something, Chandler named it a fake name and Joey assumed that that was the name of the thing. Joey then applied a label with a name to the meaning. However, for young children it could also be argued that they apply meaning to the label.

The purpose of having words is to communicate and convey meaning to another person. If the meaning of a word is not shared, there will be very little communication. Aitchison (2012:209) states that: “we cannot take it for granted that children store and retrieve words in the same way as adults. They may or they may not.” This thesis aims to contribute to our understanding of how older children organize words in their first and second language.

However, before one can retrieve words, words must be stored somewhere, and this is a key interest of psycholinguistics as well as many other fields. Some theories regarding the mental lexicon, such as WEAVER++, emphasize the importance of meaning in the structure of the mental lexicon (Levelt, 2001). An essential question is therefore how children learn the meaning of words? In her discussion of the subject, Aitchison (2012) discusses mainly young children under the age of 5. In short, she says that the first utterings of a child usually do not have meaning to the child, but they can have meaning to the parents. The next question is therefore when children add meaning to the sounds they make. Aitchison further points out that the child may link the sound to a certain understanding of either a set of events and objects, or a particular object. The continuous development depends on the negotiation between the learner (child) and the teacher (parent). Paul Bloom (2000) offers an approach that starts in the opposite direction. Bloom refers to Katherine Nelson (1988:240 cited in Bloom, 2000) who suggests that children have a certain meaning in mind and that the parents add the appropriate sounds to name the object.

The two approaches to how children learn the meaning of words also reveal quite different views on learning in general, which will not be discussed in detail as this is not within the scope of this thesis. However, it is relevant to briefly mention the main differences between the two approaches as they lay the foundation for how the research questions are phrased.

2.4.1 Theories of mind and learning

Theories of learning are deeply connected with theories of the mind and are therefore highly important for understanding the different approaches to the mental lexicon, as the answers depend on the questions that are asked, as well as how they are asked. Two quite distinct theoretical approaches, associationism on the one hand and cognitivism on the other, lay equally distinct foundations for understanding the mental lexicon.

Associationism goes back as far as to Aristotle and is a perspective which has influenced the development of various theories, such as empiricism, behaviorism and more recently connectionism. Mandelbaum (2016) explains that: "[i]n one of its senses, "associationism" refers to a theory of how organisms acquire concepts, associative structures, response biases, and even propositional knowledge". Within this approach, the emphasis is on how the individual learns all of the above, the idea being that everything can and must be learned by repeated experiences because at the starting point there was nothing. Further, such an approach to learning will emphasize how a stimuli may be conditioned in order to teach another concept. This is represented in theories of learning, such as behaviorism. Behavioral learning emphasizes that every action has a consequence which may be either positive or negative, and that these consequences are fed back into the system. In turn, the system will learn from this and can adjust future actions. The similarities with the connectionist view on language learning are rather striking, as the connectionist models of word reading, proposed by Seidenberg (2005: 239), also rely on feedback after each experience with a word.

Cognitive theories of learning are interested in how the brain is organized, how information is processed and stored. The following outline is based on Slavin (2012: 145ff). Information is introduced in a form that is picked up by one of the five senses: sight, hearing, touch, smell and taste. With regards to language, only the three first senses are applicable.

The main idea in this approach is that the sensory register holds the information briefly before it is either processed or forgotten. This is linked to the discussion in chapter 2.3.2 about priming, where one seeks to take advantage of this window of opportunity. It is unknown exactly at what point processing starts. However, as priming has been proven to have an effect on visual word recognition, it is reasonable to assume that the sensory register holds the information long enough for the words to have an effect on each other. Slavin (2012) emphasizes the importance of rehearsal of new information in relation to learning new material. In light of the research on word frequency, a high frequency word might have been rehearsed frequently and therefore be more available.

2.5 Learning to read

Theories related to early literacy have gone through massive changes since the beginning of literacy instruction. From the theories regarding the mental lexicon and visual word recognition discussed in chapter 2.1, several theories regarding early literacy, reading in general, and literacy instruction in both first and additional languages have been developed. In this chapter, two of the main theories will be discussed, as well as the most important issues which have been raised by other scholars.

Lesaux et al. (2008: 28) say that: “While children are learning to decode and encode, they must attend to the process of reconstructing the writer’s meaning”. This view picks up on the theory of speech production introduced by Levelt (2001), only in the reversed order. Where Levelt (2001) argues that speech starts with a meaning which is further combined with syntactic information at the *lemma* stage as well as morphological and phonological information at the lexeme stage, Lesaux et al. (2008) argue that when a person reads, he or she must identify the morphological, phonological and syntactic information in the lexical entry presented in print.

How is this process taught? The most common approaches to teaching literacy are through the phonological route and through the lexical route. Cook (2004) reviews these routes to literacy. The phonological route implies learning all the sounds (phonemes) used in a language and linking them to a visual sign (single letters or digraphs). This approach should enable the child to perfectly pronounce any written word by applying the rules. *Jolly phonics* (Jolly learning, 2016) is one such program used to teach reading in English. The phonological approach to reading is more common in languages with a shallower and more transparent orthography, such as Norwegian and Spanish. However, as López-Escribano (2013) claims, children who are taught reading through the phonological approach may be quite able to read words perfectly without necessarily understanding their meaning. Their reading abilities are therefore not an indication of their reading comprehension.

Another approach is to focus on the whole word and learning to recognize the whole word. This approach is based on the dual route (Cook, 2004: 16). The DRC model discussed in chapter 2.1.6 is the research behind, and thereby the foundation for, this approach to literacy instruction. However, there is a flipside to the theories on the mental lexicon and lexical access. On the flip side are the theories on how literacy should be taught. This paragraph reviews the dual route approach to literacy instruction as discussed in Cook (2004). "Dual" in the dual route approach indicates that the reader uses two stimuli entry points – the visual and the auditory – hence the focus on reading aloud in this model. The learner sees a word and ideally hears the instructor pronounce it. The visual image of the whole word is then linked to the sound image of the whole word. The whole word is further ascribed meaning in relation to the other words in the whole text. The first years of reading instruction with the dual route approach emphasize shorter words and high frequency words. The use of flash cards and speeded naming is common. It seems quite obvious that everyone who can read English or other languages with deep or opaque orthography do not memorize every single word they will be able to read later. However, the assumption is that these lexical route readers are also familiar with common phonological realizations of graphemes and can deduct a reasonable pronunciation of any written word.

Regardless of which method is used in the initial literacy instruction, the goal is to read relying on the lexical route. While weaker readers still rely on the phonological route even when they are older, stronger readers read lexically (Hagtvet et al., 2013: 21). Phonological reading is slow and can be done without understanding any of the content (Seidenberg, 2013: 336) and lexical reading is therefore a sign of a proficient reader.

2.5.1 Orthographic depth and implications for reading

Orthographic depth of a language refers to how the spoken and the written versions of a language correspond. The following outline of the differences between deep and shallow orthography is based upon Cook (2004: 10-12). Languages with a close match between spelling and pronunciation are referred to as having a shallow orthography. Cook mentions Finnish and Serbo-Croatian as having very shallow orthography, while English has a significantly deeper orthography. This influences reading instructions as each language seems to emphasize either the phonological route or the lexical route (Cook, 2004: 18).

Norwegian is classified as semi-transparent due to the several exceptions to the otherwise fairly regulated spelling (Hagtvet et al., 2013: 18). However, this description does not take into account the various spoken dialects in Norway, as will be briefly discussed in relation to compiling the list of stimuli for the experiments in chapter 3.4. Regarding the relationship between orthographic depth and early literacy skills in Norwegian, Hagtvet et al. (2013: 21) argue based on a study of 140 Norwegian children of dyslexic parents (Hagtvet and Lyster, 2003) that "[children] thus appeared to break the alphabetic code easily, presumably because of the fair degree of sound–letter regularity in combination with a teaching method that most typically emphasized sound–letter relationships". However, they also point out that many are still relatively slow readers around the age of 14-15 years, presumably because many still rely on the phonetic route rather than reading orthographically.

English is considered an orthographically deep language (Cook, 2004: 12) and the inconsistency and distance between phonemes and graphemes have long been the argument for teaching English-speaking children to read using the dual route approach (Cook, 2004: 16-28). However, the degree of literacy, or more so the lack of literacy, is a big concern for most countries. Especially children and youth are therefore frequently assessed for their literacy skills. Most countries have national tests, and additionally there is the *Programme for International Students Assessment* which is an international test which aims to test "reading, mathematical and scientific literacy in terms of general competencies" (OECD, 2016). Seidenberg (2013:331) points to the PISA assessments from 2009 and asks: "why do so many people read so poorly?" He considers three reasons for this; the deep orthography of English (Seidenberg, 2013: 334), the language variation in the classroom (Seidenberg, 2013: 347) and how reading is taught? (Seidenberg, 2013: 340).

2.5.2 Second language reading

The literature concerning reading strategies and early reading discussed in chapter 2.5 relates almost entirely to English-speaking children learning how to read English. In the Norwegian context, L1 early literacy education at school has during the last decades focused mainly on phonics, *i.e.* the ability to sound out and read syllables (Hagtvet, 2013: 21). However, the same approach has not been applied to teaching English in Norwegian schools. This will be discussed further in chapter 2.6.

Research on L2 acquisition, reading and writing has been heavily concentrated on students in higher education and has mostly relied on investigating their written work (c.f. Astika, 1993, Laufer 1991 and 1994). In the early stages, there was a particular interest in those international students who failed their exams at universities in the UK (Grabe and Kaplan, 1996: 27). Yet as schools have seen an increase in minority language populations and in the number of students who do not speak, read or write the majority language, research on L2 acquisition has been extended to include younger language learners.

The premises for teaching English as an additional language in a setting which is dominated by another language are quite different. In the settings mentioned above, it is for instance reasonable to assume that the students are exposed to the language to a large extent outside the classroom. Research on L2 reading in an English as a Foreign Language (EFL) context is somewhat limited. Within a Norwegian context, a few studies such as Drew (2009, 2010), have focused on L2 literacy instruction in elementary schools. The purpose of Drew (2009) was to investigate specially introduced programs such as the Early Years Literacy Program (EYLP). EYLP was designed to teach L1 literacy in Australia. However, after successfully adapting the program to teach L1 at Nylund Skole, the school applied the program to EFL teaching as well. This particular research is therefore less relevant for the standard taught students who participated in the experiments in this thesis.

2.6 English as L2 in Norway - EFL or ESL?

In literature about L2 acquisition, the terms English as a Foreign Language (EFL) and English as a Second Language (ESL) are defined as two distinct settings for learning a new language. ESL is often used to refer to those who learn English as an additional language within an English-speaking context, whereas EFL takes place in a context where English is less frequently used in everyday life. However, the distinction between the two terms is not clear and in literature on teaching English as an additional language, the two terms are often referred to as EFL / ESL.

In Norway, English in school is regarded as a second language. It is not possible to opt out of English within the Norwegian school system, and the students' abilities in English are tested in the standardized tests in year 5 and 8 alongside tests of abilities in L1 reading and arithmetic. English is taught from first grade and is part of the common core subjects in upper secondary education (Norwegian Directorate for Education and Training, 2013). The expected skills are described in the competence aims for years 2, 4 and 7. After year 4, students are expected to "use some common short words and simple spelling and sentence patterns" in written communication, while after year 7, they should "use basic patterns for orthography, word inflection, sentence and text construction to produce texts" (Norwegian Directorate for Education and Training, 2013). The interactive tasks for the 1st and 2nd year provided in a widely used text book are all whole words which the child must connect to either English speech, Norwegian printed words or images (Stairs 2016).

Among adults and teenagers, the use of English in everyday life has increased and influences everyday speech (Anderstrøm 2006). However, among younger children, one can assume that their exposure to English is limited and infrequent, although this is not to say that they have no exposure to English outside the classroom. One textbook used as a teacher's guide to teaching English in year 1 and 2 (Håkenstad et al., 2014) emphasizes that the children are encouraged to recognize word images (i.e. lexical reading) and suggests using flashcards with a combination of images and printed words. Suggested literature and texts are songs, poems and riddles, which often use rimes and rhymes.

Teaching of foreign languages in Norway has a long history, as long as the history of public schools. Latin and Greek were the two classical languages which students in higher education were required to learn in order to become well-educated members of society. However, towards the end of the 18th century, the modern languages English, French, and German were introduced at one school (Fenner, 2005: 85-86). The main argument in favor of the modern languages was that they were living languages and therefore important in terms of their contemporaneity. However, as Fenner (2005) notes, the teachers often had no or little training in teaching English.

The approaches to foreign language teaching within the Norwegian school system have changed radically over the years from a heavy emphasis on grammar rules and translation in early days and up to the communicative approach which is more common in classrooms today (Tornberg, 2012). Tornberg (2012) explains that when there were few teachers who used the language outside the classroom, the emphasis was on grammar and syntactic properties. When there was a shift from Latin to languages in nearby countries, the emphasis also shifted towards a proper pronunciation and learned phrases. The foundation of the International Phonetic Alphabet in 1886 aided teachers in achieving this, as did the establishment of the Berlitz Schools of Language. Their idea was that by memorizing the proper words in their proper form with the proper pronunciation, the student would learn the structure of the language. However, with the emphasis on all these aspects, the meaning of words was somewhat neglected. The audio-lingual method became popular after the Second World War (Tornberg, 2012: 35) and is strongly linked to the ideas of Skinner and to behaviorism as a theory of learning (Tornberg, 2012: 37). Whether the focus was on grammatical rules, pronunciation or the communicative aspect of languages, what seems clear is that each approach emphasizes a certain aspect of the lexical entries as outlined by Levelt (1989).

2.7 Summary

This chapter has discussed seven models on lexical access, all of which differ somehow. The main differences between the approaches to researching the mental lexicon are two fundamental beliefs; one that assumes that there is an inherent structure to discover and the other which assumes that the brain is constantly learning and developing the structure. Yet, all seem to agree that there are links between the lexical information in our brains, and the way this information is spread out on different levels or in different systems within the greater system.

The most common methodological approaches to studying this are lexical decision making and naming tasks. Both tasks can include a distractor word, or a prime, which is intended to pre-activate the target word in either the lexical decision task or the naming task. This study consists of a series of lexical decision tasks with word-to-word priming. The idea is that by activating one node among other connected nodes, the other nodes will then have an excitatory effect if that node is activated shortly afterward. This implies that if priming activates a node, repeated activation of the same node both as prime and target will have a strong effect. To examine this, one part of the experiments will be same word priming.

The hypotheses offered by the researchers suggest that the words can be linked through either meaning or form. Levelt (1989, 2001) argues that the lexical entries (i.e. words) consist of two main parts, and that the *lemma*, which contains the meaning and syntactic information, is the starting point for speech production. Because the *lemma* is selected first, Levelt argues that lexical entries must be connected on a *lemma* stage. This implies that meaning related words are linked in the lexical selection network. In order to examine this proposition, the effect of priming with meaning related words will be tested in the experiments in this thesis.

Conversely, Seidenberg's PDP model places more emphasis on the relationship between the various orthographic levels and the corresponding phonological levels. These two dimensions represent two kinds of linkage between word forms. This suggests that words of similar forms are connected in the mental lexicon. Consequently, the experiment will also examine the effect of priming with form relationships between the words. The words in the experiments will be both phonologically and orthographically identical in either the first or the final syllable.

The study therefore examines relative effects of three types of priming; same-word, meaning-related and form-related priming. In the following chapter, the methods used will be discussed in greater detail.

3 Methodology

In order to examine these ideas, an experiment was conducted testing the effects of prime words of different kinds on lexical decision-making tasks in L1 and L2 in a group of Norwegian school children.

The design of the experiments is based on earlier experiments run by Stremme (2015), who conducted a cross-linguistic study with adult bilingual and L2 novice participants investigating form and meaning influence on Norwegian and English stimuli. Prof. Christer Johansson supervised her thesis and has provided valuable help with designing the experiments for this thesis as well. This project is done in cooperation with Vibeke Rønneberg and The Reading Centre at the University of Stavanger.

3.1 The participants

The data for this thesis are the results from two different experiments conducted on a selection of year six students in Stavanger, Norway. The participants were preselected by Vibeke Rønneberg as part of her PhD project and she registered the project with Norsk Samfunnsvitenskapelig Datatjeneste (NSD).

The participants in the experiments were children attending two different elementary schools within the city of Stavanger. They are students from three groups, one group from school A and two groups from school B. All students participated in the L1 experiment which took place in April 2015, while only students from school B participated in the L2 experiment, which was done five months later, in September 2015. All the students in the participating groups were invited to take part in the experiment. However, as the study involved children, student participation in the study required prior consent by their parents or guardians. A letter with information about the study was given to the parents and/or guardians prior to the experiment. Because the two experiments could not be conducted at the same time, a second letter of consent was sent out prior to the second experiment. This was done through a consent slip which students took home in advance of each experiment. Only students whose parent or guardian had signed the consent slip have been included in this study. See appendix for a copy of the consent forms.

Both schools perform at or above the national average in standardized national tests in reading and English according to the published results from the national tests (Norwegian Directorate for Education and Training, 2013 and 2014). These results reflect the average of all students who sit the tests. Especially weak students or students who for personal reasons do not wish to sit the tests, may ask to be exempt. These students are therefore not included in the average results from the school. However, as will be discussed in chapter 4.1, analytical measures will be taken to ensure that the findings are representative. Every fall term, year five students sit three standardized national tests; English, reading (in Norwegian) and numeracy. The scores from year five are divided into three proficiency levels; low (1), middle (2) and high (3) (Haugberg, 2014). School A scored somewhat better than school B on the standardized national tests in 2014, whereas school B was close to, or minimally better than, the regional average. Further details cannot be revealed in the thesis in order to protect the students' anonymity. For individual school level results, only the 2014 numbers are publicly available. For city and regional level there are comparable numbers for 2013 and 2014. The children in this study sat the tests in 2013. The average numbers for the city and the region in English and Reading improve minimally, whereas the average results for numeracy improve the most. There is therefore little reason to suspect that the students in this thesis scored very differently than last year's students. The academic performance of students at these schools is considered on average to be fairly close to the general population of Norwegian children in this age group.

3.2 Experiment design

The first experiment is in Norwegian, the students' first language. The second experiment is in their second language, English. The students have been formally exposed to English since they started formal education in Norway. Norwegian children are required to start school when they are 6 years old. English is introduced orally to the children in the year 1. They are not required to read or write English until they start year 3 (Norwegian Directorate for Education and Training, 2013). Their introduction to English may be compared to their introduction to Norwegian as both languages are first introduced orally and the written language is only introduced later.

The experiments in this thesis are similar to each other, but the English version is smaller due to the more limited vocabulary to which the children are likely to have been exposed. The task in both experiments is to decide whether a word is a real word or a pseudo-word. An example of a real Norwegian target word is <SKAP> and a pseudo-word is <LIMGER>. An English target word is <LAKE> and a pseudo-word <WHIASH>. All words will be presented twice to the participant, once with a prime and once without a prime. The purpose is to measure the different reaction times between primed and unprimed words. The experiments are conducted on the computers (property of the schools) running the EyeWrite software (Simpson and Torrence, 2007) which automatically registers the RT.

The first block of the experiment is a trial session where the participants receive onscreen feedback as to whether the response is correct or incorrect. During the actual experiment, no such feedback regarding correctness is provided. However, if participants take too long to respond, a message "Trykk litt raskere!" (*Press a little faster*!) would appear onscreen.

The program shows a target word on screen for up to 1000 milliseconds, or until it is dismissed or accepted by the participant. The participant must as quickly as possible choose to dismiss the word as a pseudo-word or accept it as a real word with lexical meaning. The participants are instructed to make a decision quickly, however they were also told that they would not be expected to explain or translate any words in the experiment. Figure 3.1 below illustrates the how the experiment was presented to the participants on screen.

Figure 3.1 Order of the experiment in baseline

*	(blank screen)	TARGET
Fixation point	50 ms	Up to 1000 ms

Figure 3.2 Order of the experiment with priming

*	Prime	(blank screen)	TARGET
Fixation point	100 ms	50 ms	Up to 1000 ms

The entire experiment is done twice, once with a prime and once without a prime. Primes are words that may be related to the target word either by meaning or form, or have no relation at all to the target. Primes are shown on screen for 100ms prior to the target word. The purpose of showing the words both primed and unprimed is to be able to create a baseline for RTs. In order to investigate whether the introduction of a prime has an effect, it is necessary to measure unprimed responses as well as primed responses. Seeing the words for the second time, either as primed or baseline, may have an unintended priming effect, as it is unclear how long the priming effect lasts (Forster and Davis, 1984). Half of the participants therefore see unprimed words first (baseline first treatment), while the other half sees the primed words first (prime first treatment). If repetition has an effect, it should cancel out if presentations are counterbalanced. In the statistical analysis, an estimated baseline will be calculated for each word based on how fast all participants have responded to that word in the baseline. The estimated baseline for each word will also be adjusted for how quickly or slowly that particular participant responds in general to all words in the experiment. In addition to the real words shown on screen, the children will see the same amount of pseudo-words, both without any primes and with real word primes.

3.3 Conducting the experiments

Both experiments were conducted at the students' schools during school hours. Both schools have dedicated rooms equipped with computers and the students have their own unique log in credentials. The computers are stationary with standard keyboards and screens. The students are familiar with using these computers. At school A, there were enough computers to accommodate the entire class in one session. At school B, there were only 12 computers that could run the necessary software and the experiment. Each group was therefore divided into two sessions. However, all students needed assistance entering the correct identification number which had been assigned to them. Furthermore, the children had randomly been assigned to either of the two conditions – prime or baseline first – and the researcher entered this information. If prime first was chosen, the participant would first see the target words primed and then unprimed. Due to this process, none of the students started at the exact same time and none of them ended at the same time. This did cause some noise and possible distraction to those who had either already started the experiment or had not finished while others were waiting to get started or were leaving the room.

Prior to taking the students to the computer room, they were told what would happen. They were told that they would take part in an experiment where their task was to determine if the word in capital letters on the screen was a real word or a pseudo-word. They were shown A4 sheets with replicas of the experiment. First they were shown the <*> symbol, then a word in lower case letters and at last, a word in capital letters. The first example ended with a real word and the second example ended with a pseudo-word. This led to a short discussion about pseudo-words. Students were reassured that the real words would be normal words and that they should in any case answer to the best of their knowledge. For the English words, students were further instructed to go by their gut feeling and that they were not required to be able to explain, translate or pronounce the word. Prior to both experiments, students were told that the words in lower case letters would only appear for a short time on screen and that they were not required to be able to read that word. The instructions were repeated on screen once they had initiated the program.

3.4 Conditions of the experimental stimuli

In order to examine propositions from the theory, the words were primed with different types of prime words. However, t is necessary to briefly discuss the different conditions. The aim of the experiment is to investigate the effect which different words have on each other, and in order to do so, the stimuli are either real words categorized into five different conditions or they are pseudo-words.

In addition, there are other variables that might influence the RT of a lexical decision task. As discussed in chapter 2.2, the neighborhood size and density will most likely influence the RT. Furthermore, New et al. (2006) sheds new light on the role of word length in visual word recognition. They report that words with three to five letters have a facilitory effect while five to eight letters have a null effect. Words with more letters were found to have an inhibitory effect. New et al. (2006: 9) also report that they cross-checked to investigate if numbers of letters might correlate with number of syllables. They claim that this is not the case, although they note that an extra syllable does add on average 20ms per syllable (New et al., 2006: 12).

The relationship between the prime and the target in a word pair may be one of four types; same word, meaning related, form related or unrelated.

Table 3-1 Matrix of conditions

	Same word	Meaning related	Shared first syllable	Shared last syllable	Unrelated
Meaning	+	+	-	-	-
Form	+	-	+	+	-

3.4.1 Same word

Condition number one is same word priming. The prime and the target word are related in both meaning and form. The primes are written in lower case letters, while the target words are written in capital letters. Cattell (1886a: 64) finds that there is no difference in how long it takes to read words written in small and capital letters.

Table 3-2 Same word condition in both experiments

L1			L2	
Prime	**TARGET**	**translation**	**Prime**	**TARGET**
agent	AGENT	Agent	meal	MEAL
kikkert	KIKKERT	Binoculars	scarf	SCARF
eske	ESKE	Box	goal	GOAL
stang	STANG	Pole	bakery	BAKERY
papir	PAPIR	Paper	friend	FRIEND
stein	STEIN	Stone	name	NAME
skygge	SKYGGE	Shadow	voice	VOICE
fjell	FJELL	Mountain	message	MESSAGE
kurv	KURV	Basket	carpet	CARPET
benk	BENK	Bench	beast	BEAST
ring	RING	Ring		
kule	KULE	Bullet		
piano	PIANO	Piano		
diamant	DIAMANT	Diamond		
telefon	TELEFON	Telephone		

3.4.2 Meaning-related

Condition number two is meaning-related. Meaning relations between words is the most ambiguous of the conditions. Jackson and Amvelav (2000: 106-122) discuss various kinds of meaning relations between words. Meaning-related words can refer to sense relations, collocations and semantic fields. The sense relations are synonymy, antonymy, hyponymy and meronymy. Antonyms do not share meaning as they refer to opposites and are therefore not included in this study. Synonyms are defined by the *Oxford English Dictionary*:

> Strictly, a word having the same sense as another (in the same language); but more usually, either or any of two or more words (in the same language) having the same general sense, but possessing each of them meanings which are not shared by the other or others, or having different shades of meaning or implications appropriate to different contexts
>
> (OED online 2016)

The part of the definition which refers to the possibility of the two words overlapping in most senses, but still allowing for the possibility of each possessing unique senses, have led to the subcategorization of synonyms into strict and loose synonyms. In their discussion of synonyms, Jackson and Amvela (2000) raise the point that synonyms are often used in different contexts and have different degrees of formality. This may lead to the possibility of synonyms having different degrees of frequency. As previously mentioned, all the words in the experiment should be within a certain range of frequency and therefore only some of the word pairs can be defined as synonymous. Hyponyms and meronyms both refer to the hierarchical structure of meaning. The relationship between meronyms can be described as one word being “a part of” another, such as the <nose> is a part of the <face>. Hyponyms are defined as words related in the sense that they are “a kind of” each other. A <house> is a kind of <building>, often with one being more general than the other. Two words may be co-hyponyms of a higher level word. As Table 2-1 and 2-2 below show, the words in the experiments can be classified as either co-hyponyms or meronyms. The experiments are not designed to investigate differences between different kinds of meaning relations. Regardless of the findings in the analysis, it might be worth investigating this in another experiment. However, in order to have sufficient numbers of word pairs qualifying to each relation and not exceed the time frame for completing the experiment, whereas this experiment wants to contrast the effect of meaning-related primes with those of form-related as well as same-word primes.

Tables 3-2 and 3-3 below show the meaning related word pairs used in the experiments. Due to the importance of meaning in this condition, an English translation has been supplied for the benefit of the reader. The translations were not part of the experiment. As both Tables 3-2 and 3-3 show, the meaning relations within the word pairs are similar across languages and are often hyponyms or loose synonyms.

Table 3-3 L1 Meaning related word pairs (*with English translation*)

Prime	**TARGET**	**Prime translated**	**TARGET translated**
arm	BEIN	*arm*	*LEG*
maleri	BILDE	*painting*	*PICTURE*
linser	BRILLER	*lenses*	*GLASSES*
sang	DIKT	*song*	*POEM*
bil	DROSJE	*car*	*TAXI*
selskap	FEST	*company /party*	*PARTY*
tommel	FINGER	*thumb*	*FINGER*
vegg	GULV	*wall*	*FLOOR*
bord	STOL	*table*	*CHAIR*
beholder	FLASKE	*container*	*BOTTLE*
bjørn	ULV	*bear*	*WOLF*
fane	FLAGG	*banner*	*FLAG*
sjekk	KONTROLL	*check*	*VERIFICATION*
jord	GRUS	*earth*	*GRAVEL*
hylle	SKAP	*shelf*	*CUPBOARD*

Table 3-4 L2 Meaning related word pairs

Prime	TARGET
gloves	MITTENS
head	FACE
chicken	HEN
fruit	BANANA
bread	DOUGH
desk	TABLE
cottage	LODGE
salad	LETTUCE
lamb	SHEEP
kitten	PUPPY

3.4.3 Form-related

The third and fourth conditions are related to form similarity. The experiments include two types of form-like words, one with a shared first syllable and one with a shared last syllable. Within a word pair, the first or the last syllables are phonemically and graphically identical. This is to be understood as spelled and pronounced identically. However, the emphasis is on spelling due to the idiosyncratic variations in pronunciation, as well as geographical or socioeconomic variations.

Table 3-3 below shows the Norwegian stimuli in the conditions shared first or last syllables. A symbol < | > has been added only to this table to indicate the border between the syllables. The words in these conditions have either one or two syllables. Table 3-4 shows the English list of stimuli in the conditions shared first or last syllable. The English phonemic transcriptions are from *Longman Pronunciation Dictionary* (Wells, 2008) and are provided to support the claim that the relevant syllables of the words are phonemically identical. The transcription shows the boundary between syllables by inserting a space.

No such transcription is provided for the Norwegian stimuli in Table 3-3 due to the degree of variation within the Norwegian spoken language. The main Norwegian dictionary *Bokmålsordboka* does not provide a phonetic guide to pronunciation whilst the LEXIN online dictionaries (2016) only supply the variety usually found in the dialects spoken in the eastern parts of Norway. Handbooks to Norwegian phonetics, such as Slethei (1996), take all varieties into account and link phonetic features to the geographical locations where they are most common. However, a narrow phonetic transcription of the most common local varieties would still not cover all varieties of pronunciation due to idiosyncratic differences. English also has lots of variation in spoken language, but that Norwegian children are generally taught standardized pronunciation close to the Oxford English of the dictionary and mostly do not speak different English dialects. Nonetheless, idiosyncratic differences in English are probably larger due to differences in skills. However, as discussed in chapter 2.6.2, whereas English is regarded as a language with deep orthography where there sounds and symbols do not correspond (Cook, 2004:11), Norwegian is much shallower and within the different spoken varieties, it is consistent in terms of a match between symbol and pronunciation. Rhymes can therefore be recognized based on spelling.

Table 3-5 L1 shared first and shared last syllable[3]

Shared first syllable		**Shared last syllable**	
an|satt	AN|KEL	krutt	GUTT
napp	NATT	ko|de	HO|DE
flom	FLOKK	pant	KANT
pass	PARK	ma|sse	KLA|SSE
klyng|e	KLY|PE	tra|ppa	PA|PPA
lam	LAPP	gull	HULL
la|ser	LA|GER	fart	KART
pels	PENN	test	HEST
skilt	SKIP	kram|pe	LAM|PE
ha|re	HA|GE	plass	GLASS
da|me	DA|TO	spytt	PYTT
vin|kel	VIN|DU	hekk	SEKK
fisk	FILM	be|vis	A|VIS
pest	PEIS	bror	SPOR
le|ke	LE|GE	havn	NAVN

[3] See appendix for translation

Table 3-6 L2 shared first and shared last syllable[4]

First syllable				Last syllable			
/greɪp/	grape	GRAVE	/greɪv/	/bʊk/	book	HOOK	/hʊk/
/ˈbʌt ə/	butter	BUTTON	/ˈbʌt ᵊn/	/ˈlaɪ‿ən/	lion	ONION	/ˈʌn jən/
/hænd/	hand	HAM	/hæm/	/hæt/	hat	RAT	/ræt/
/fɒks/	fox	FOG	/fɒg/	/leg/	leg	EGG	/eg/
/ˈtʌm i/	tummy	TURTLE	/ˈtɜːt ᵊl/	/klɒk/	clock	STOCK	/stɒk/
/biːn/	bean	BEACH	/biːtʃ/	/bɔːl/	ball	HALL	/hɔːl/
/ˈmʌn i/	money	MONKEY	/ˈmʌŋk i/	/ˈkænd ᵊl/	candle	HANDLE	/ˈhænd ᵊl/
/keɪk/	cake	CAGE	/keɪdʒ/	/stəʊn/	stone	BONE	/bəʊn/
/ruːf/	roof	ROOSTER	/ˈruːst ə/	/sneɪk/	snake	LAKE	/leɪk/
/kʌp/	cup	CUB	/kʌb/	/gəʊt/	goat	OAT	/əʊt/

3.4.4 Unrelated

Unrelated words do not share meaning or form in any of the above-mentioned conditions. The purpose of these words is to compare the other conditions against the RTs of the unrelated words. In order to ensure that these words are not related to any of the other words in the experiment, there is a possibility that these words are slightly harder to read despite being within the acceptable frequency range. The L1 average word length within unrelated words is 5.36 letters whilst the overall average word length is 5.27 letters. For the L2 experiment, the average word length is 6.15 letters whilst the overall average is 5.7 letters. However for the L2 stimuli, the additional factor that students have limited vocabulary restricts the set of words which could be chosen. Whilst it is fairly straight forward to determine that a word is related to another word, it is more challenging to ensure that words are not related to each other either in form or meaning. Within a particular context, any pair could potentially be meaning related. One could argue that there is a meaning relationship between *robber* and *police* which are both primes in the unrelated group. For the purposes of the present experiment, unrelated refers to the range of meaning relationships within the hierarchy of structure of meaning outlined in 3.4.2.

[4] Phonemic transcription as provided by Wells (2008)

Table 3-7 L1 Unrelated word pairs with translation

Prime	TARGET	Prime translated	TARGET translated
bukse	PISTOL	trousers	GUN
pute	NESE	pillow	NOSE
skjorte	SOPP	shirt	MUSHROOM
torsk	SKOLE	cod	SCHOOL
slips	SOFA	necktie	SOFA
modell	SPILL	model	GAME
kjole	SPORT	dress	SPORT
ramme	SVETTE	frame	SWEAT
koffert	SANGER	suitcase	SINGER
nøkkel	MALING	key	PAINT
kontor	SØLV	office	SILVER
maske	SKØYTER	mask	SKATES
blyant	HØVDING	pencil	CHIEF
spade	SLIM	spade	SLIME
hummer	VITNE	lobster	WITNESS

Table 3-8 L2 Unrelated word pairs

prime	TARGET
robber	PUMPKIN
airport	CHIMNEY
bacon	SURFACE
colour	DUSTBIN
cheek	RADISH
treasure	FENCE
coin	GHOST
chocolate	SKIRT
police	VAMPIRE
berry	WINDOW

3.4.5 Pseudo-words

The pseudo-words are an essential part of the lexical decision-making experiment as the participants have to choose whether the target word is a real word or a pseudo-word. Pseudo-words only appear as target words in this experiment. In the priming part of the experiment, they are primed by a set of words unrelated to any of the other real words in the experiment.

The primes in the pseudo-word pairs are normal words, but most likely harder to read as they may be less frequent and longer. Because there are several known issues related to pseudo-words in lexical decision tasks, the most problematic issues will be briefly discussed in the follow section.

A common solution to creating pseudo-words is to change one or more letters in a word, and often replace a vowel with another vowel and a consonant with another consonant to make sure that the word is still pronounceable (Meyer and Schvaneveldt, 1971: 228). However, if only one letter is replaced, one implication of this is that the pseudo-word would be part of the orthographic neighborhood of the real word (New et al, 2006: 11). Tainturier et al. (2013: 6) report that "the results […] have shown that pseudo-words can prime phonological word neighbors as long as the phonological distance between the two does not exceed one or two phonetic features". Although their research is based on phonological input rather than visual recognition, it is reasonable to assume that the same conclusion may be drawn with regards to orthographic neighborhoods. Another kind of pseudo-word would be pseudo-homophones, as mentioned by Coltheart et al. (1977). Pseudo-homophones are words that would sound like real words, but are spelled incorrectly. None of the stimuli in this thesis are pseudo-homophones,

Perea et al. (2005) investigate the frequency effect for pseudo-words in lexical decision tasks in Spanish with native speakers. A low-frequency pseudo-word according to their definition is a pseudo-word based on a low frequency word and a high frequency pseudo-word is based on a high frequency word. They further distinguish between pseudo-words where letters are replaced, which are referred to as replacement-letter pseudo-words, and those where letters have swapped places, which are referred to as transposed-letter pseudo-words. The study finds that high frequency replacement-letter pseudo-words are recognized faster than low-frequency words. However, the authors note that the transposed-letter pseudo-words are more similar to the actual words and therefore are more difficult to read than the real word. Their research demonstrates that it is not irrelevant how pseudo-words are created if the aim is to compare reading of words to pseudo-words.

Due to these issues, which have not been addressed in the process of creating pseudo-words for the experiments in this thesis, none of the analyses will focus on how the participants react to pseudo-words in the experiments. Nevertheless, Altarriba and Basnight-Brown (2007:3) recommend that the distribution of real words and pseudo-words should be .5 to ensure an unbiased approach. The distribution of pseudo-words is more important than the proportion of related words to unrelated words, which Altarriba and Basnight-Brown (2007:3) call the relatedness proportion. In the experiments in this thesis, the aim is to have a .5 distribution of pseudo-words, and to keep the proportion between the other five conditions equal.

Table 3-8 below shows a sample of the pseudo-words used in the experiments in this thesis. A full list of target pseudo-words and their real word primes may be found in the appendix.

Table 3-9 Samples of pseudo-words

Norwegian pseudo-words	English pseudo-words
KNIM	SPIPS
ISUT	GROCKET
MASLIG	SWACE
NORMIGA	BREETS
KLIDDER	CHASK

The 75 pseudo-words for the Norwegian experiment were created in collaboration with prof. Christer Johansson at the University of Bergen. The requirement was that the pseudo-words should conform to Norwegian phonotactics, i.e. be possible to pronounce by applying Norwegian rules concerning possible combinations and order of phonemes and syllables, but they should not have any lexical meaning. Some of the words are similar to real words, while others are not even close. Unlike the English pseudo-words, the Norwegian pseudo-words are not intended to be related to the prime at all. The assumption is that the more similar the pseudo-words are to real words, the harder the test would be.

For the English experiment, 50 words were selected to prime the pseudo-words. These words were uploaded to Wuggy, a software program that creates pseudo-words (Keuleers and Brysbaert, 2010). The output was a selection of 50 pseudo-words, each of which corresponds to English phonotactics and matches its prime in number of syllables and letters per word. In terms of pseudo-word classification, these are more like replacement-letter pseudo-words, but with multiple letters replaced.

3.5 The Norwegian experiment

Norway has two written languages that are mutually comprehensible, *bokmål* and *nynorsk*. The Norwegian experiment uses *bokmål*. All students are required to read and write both during their primary and secondary education, but one is chosen as the primary language, which for all students in this experiment is bokmål. Some of the students may be influenced in their home environment by *nynorsk* due to parents' preferences and because the dominant dialect in the geographical area is more closely linked to *nynorsk*. However, this should not influence the children's ability to read the words in the experiment as the school district[5], which operates both schools, uses *bokmål* as its main language (Lovdata, 2007). Therefore, the children's formal education in reading and writing will have been in *bokmål*. Furthermore, between the two languages, nouns are nearly identical in their singular, indefinite form, which is the form used in the experiment.

The intention was to have 20 word pairs in each condition in the experiment, but some trial runs indicated that it would take too long to complete an experiment of that size. Therefore the experiment was scaled down to 15 word pairs (a prime and a target word) in each condition and 75 pseudo-word pairs (real word prime and pseudo-word target). There are five different relationships between prime and target word: same word, meaning related, head rhyme, end rhyme and no relation. In addition to fitting into one of the categories, several other criteria have to be fulfilled, such as word class, length and frequency.

A selection of 5x15 word pairs was compiled according to the two first criteria. The words are concrete nouns in their indefinite and singular form. In Norwegian, a suffix is added to create a definite form both in singular and in plural. The suffix is dependent on the grammatical gender of the word. Norwegian has three grammatical genders: masculine, feminine and neutral. Due to the condition of end-rhyme, it is necessary to use the indefinite form as otherwise it would be difficult to create good pairs. The suffix would in most cases also add an extra syllable and they would be very similar. Finally, most feminine nouns may legally also be treated as a masculine noun. Excluding the definite form eliminates both of the issues related to form.

The length criterion is divided in two aspects: amount of syllables and number of letters. The minimum number of syllables is one and the maximum is three syllables. Most of

[5] Stavanger kommune

the words have one or two syllables. The minimum word length is three letters and the maximum word length is nine letters. The gives an average word length of 5.27 letters. The reason for this criterion is that the participants should not use a visual cue like length to determine if a word is real or not. A sub-criterion dealing with vowel quality is also introduced here. The vowel qualities in the form-like syllables should be phonemically identical in order for the words to share a visual form as well as an auditory form.

One purpose of the frequency criterion is that the participants should be familiar with the words. A second purpose is to ensure that the words are equally frequent and comparable both on a word pair level as well as in the experiment overall.

It is an aim to compile a list of stimuli which consists of normal words. To ensure that they are equally normal and comparable each word was checked for frequency. To find the frequency all the words classified in the real word pairs have been checked for frequency in the Norwegian Newspaper Corpus (NCC) (Aviskorpus, n.d.). The words were looked up in the NCC on April 10, 2015. The corpus had at the time 1 426 454 274 tokens. The corpus consists of all words found in web-editions of 24 Norwegian newspapers (Aviskorpus, n.d.) since 1998 and continues to expand every day with new texts being published. This includes misspelled and new words as well as ordinary words. The corpus is therefore not a random selection of all Norwegian words. Misspelled words are included in the corpus, but are infrequent. Some particularly difficult and unusual words may also be included, but are likely to be infrequent. Newspapers are likely to eliminate a large number of rare words as they depend on readers' abilities to understand what the papers write without relying too heavily on context. The normal distribution scale for words in the language as a whole as well as the words in the corpus is likely to be disproportionate because a few words are used very frequently, as some words will be very common and quite a few words will rarely be used. Within the newspaper corpus, some words have a very high frequency while others have a low frequency. The corpus therefore has a positively skewed distribution that makes it difficult to set an acceptable range for frequency. A common solution to this problem is to use a log transformation to make a positive skew less skewed. A log transformation is to use a log version of the number rather than the number itself (Lane, n.d.: 579). The calculations suggested that the outliers in the first version of the selection were values lower than 175 and higher than 295000. As previously mentioned, it was decided to downscale the size of the experiment to 15 word pairs and the words classified as outliers were eliminated.

As indicated by Coltheart et al. (2001) frequency of words may have an effect on latencies. Therefore a table of frequency distributions of words was created, showing that the experiment words follow a log-normal distribution. In order to test this, the Kolmogorov-Smirnov test and the Shapiro-Wilk test were used. These show that there is no significant difference to the normal distribution with the same parameters. The Kolmogorov-Smirnov-test shows that D=0.061 with P=0.709, and the Shapiro-Wilk-test show that W=0.988 with P=0.292. Figures 3.3 and 3.4 show the normal distribution of the stimuli.

Figure 3.3 L1 stimuli histogram

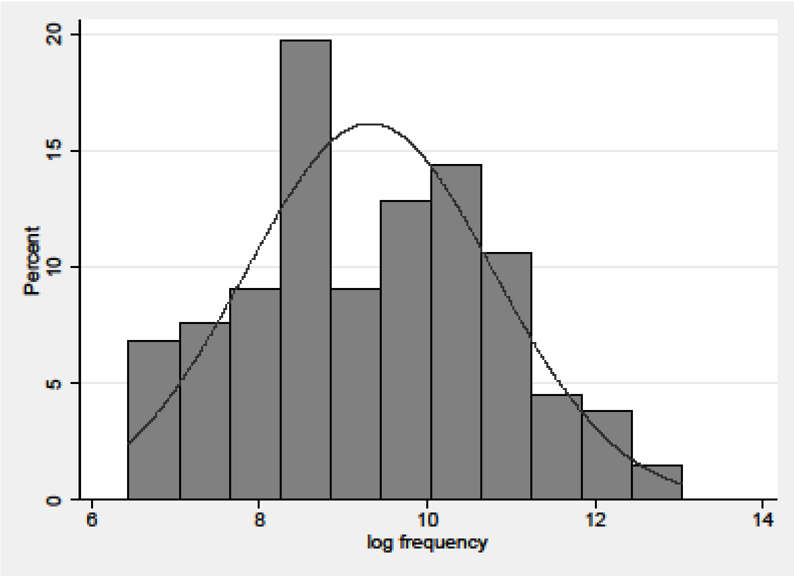
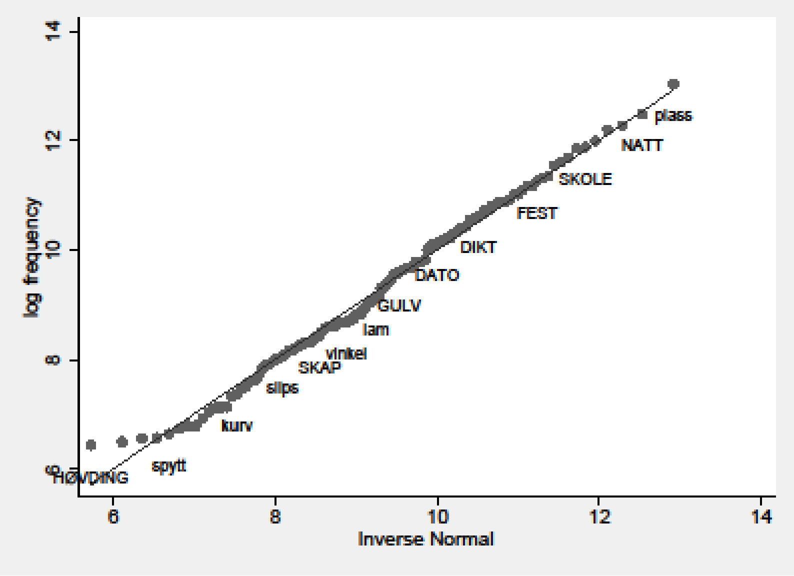


Figure 3.3 shows the distribution of the frequency for the words in NCC. Because they follow a log-normal distribution, the log scale is used for the frequencies. This histogram shows that the distribution of logged frequencies reasonably resembles the normal distribution shown as a solid line in the figure. Most words have a log frequency between 8 and 11 which corresponds to actual frequencies between approximately 3000 and 60000 in the corpus. The least frequent word is <høvding> with a frequency of 629 and the most frequent word is <plass> with a frequency of 458558.

Figure 3.4 shows a quantile plot for the logged frequencies against the normal distribution. As the plot shows, the distribution of frequencies traces the normal distribution closely at all levels of the distribution. The only exception being in the very low range of the distribution which can be attributed to the censoring of very infrequent words with which the participants are less likely to be familiar.

Figure 3.4 L1 Stimuli quantile plot



3.6 The English experiment

The English experiment is of a somewhat smaller scale due to the students' more limited vocabulary. It includes 10 word pairs in each condition (same word, meaning related, head rhyme, end rhyme and no relation). In addition to fitting into one of the categories, several other criteria have to be fulfilled, which are described below.

The words are concrete nouns and in their singular form. One word pair appears in plural because this is how the children have been exposed to the words: <gloves> and <mittens>. Lengthwise, the English words follow similar criteria to the criteria in the Norwegian experiment. The words in the selection have one to three syllables, with a majority having one or two. The minimum word length is three letters and the maximum is eight letters; the average word length is 5.7 letters. English words tend to have more letters per syllable than Norwegian, which had on average 5.2 letters per word. The difficulty level is therefore likely to be comparable. The reasoning behind using the number of syllables as a criterion is, as in Norwegian, that a deviant word length may function as a visual cue to the participants, indicating whether the word is real or not. Additionally, a longer word may contribute to an increase in the cognitive load. With the time constraint, it might lead to more words timing out before the student can accept or dismiss the word.

The purpose of checking the frequencies for the words in the Norwegian (L1) list of stimuli was to ensure that the words in the experiment are words which one can assume that the children are familiar with. However, if the same procedure had been adhered to in compiling the list of stimuli in English (L2), the children would most likely not be familiar with the words. Therefore, the English list of stimuli is gathered from the the year five English textbook, Stairs 5, which the students can be assumed to be familiar with. To ensure that the students are familiar with the real words, a separate test was given to them. The 20 words which are in some way meaning related were illustrated on a sheet of paper and students were asked to name the objects based on a list of words provided at the top of the page. One word and image was pre-matched as an example. The purpose of this test is to rule out that the variable meaning relation is not harmed by the fact that the students are completely unfamiliar with the words. The students scored on average 15 out of 19 possible correct answers.

4 Findings

This chapter will discuss the findings of the experiments discussed in the previous chapter. The research question which the experiments were designed to answer was how form and meaning priming affect children's reaction time in lexical decision tasks in their first and second language. First, some descriptive statistics will be presented in order to provide a solid framework for the more complex analysis. A discussion of the dependent variable and the linear mixed models analysis of the RT follows. The two experiments will be analyzed and discussed separately but relevant commonalities and differences will be highlighted when appropriate.

4.1 Descriptive statistics

4.1.1 Dependent variable

The dependent variable is the RT which is the time each participant uses from the target word appears on screen until he or she presses a key to respond to the decision making task: is this word a real word or a non-word?

Only correct answers within the time frame of 345ms and 1000ms are included in the analysis. RTs quicker than 345ms and slower than 1000ms are considered outliers because faster responses are not real responses and slower RTs indicate other issues such as being distracted by someone else or not concentrating on the task. As discussed in chapter 2.3.2, there is a limit to how fast the brain can possibly register stimuli. Grigsby and Stevens (2000: 253-254) further discuss the findings from Benjamin Libet's research on how long it takes for the brain to react to stimuli, or, in other words, the time frame between the onset of the intention and when the action is commenced. Following a series of experiments, Libet indicates that this time frame is 345 ms. Therefore, it is likely that RTs faster than 345ms are guesses rather than actual responses to the stimuli, and have to be excluded. On the other side of the time frame is the question of how much time participants should be allowed before they are cut off. The assumption is that, given enough time, all participants would be able to read any word.

4.1.2 Independent variable

The independent variable is what is assumed to influence the dependent variable, the RT. In these experiments the conditions of the prime may or may not influence the RT. The conditions in this experiment are *same* word, *meaning*-related word, shared *first syllable*, shared *last syllable* and *unrelated*.

4.1.3 Distribution of correct answers.

As can be seen in Table 4-1 below, all the correct answers provided are distributed quite evenly across languages and conditions. Each condition makes up 20%. This is reassuring as all the correct answers could in theory have been clustered in only a few conditions, or at least have been clustered unevenly. The exceptions are from the L2 experiment. Same word priming make up a larger share of correctly answered words than the overall average with almost 25%, while unrelated priming make up a lower proportion than the overall average with only 17%. This indicates that same word priming in L2, regardless of RTs, encourages more correct answers while unrelated priming is not conducive to correct responses. However, these numbers are mean values and do no account for individual differences.

Table 4-1 Distribution of correct answers by condition and language when primed

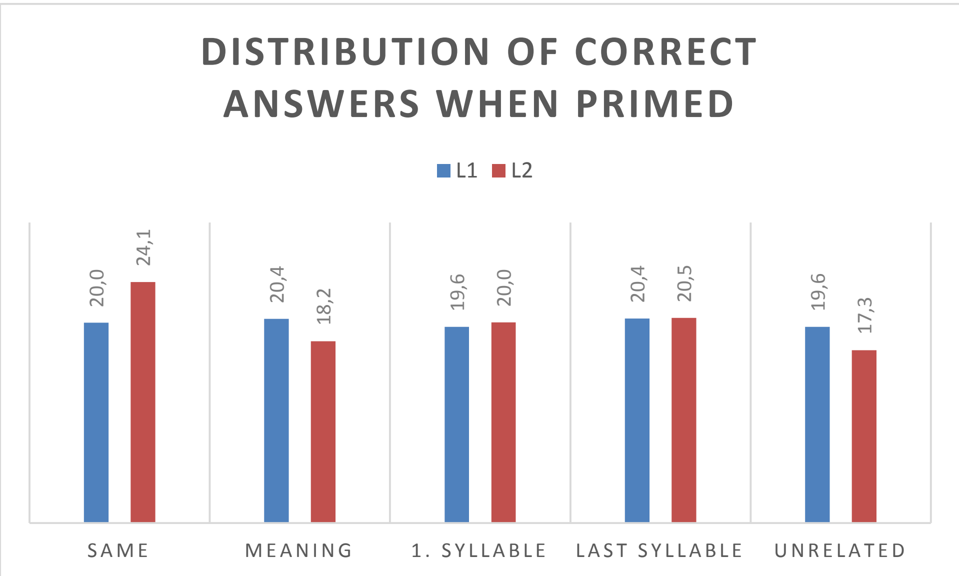


Table 4-2 below shows the wide distribution of correct answers both between the various subjects as well as between target words. The distribution of correct answers per person varies from 16% to 97% in L1 and from 28% to 86% in L2. In terms of target words, the difference between the words with the most and the fewest correct answers is much higher in L2 than in L1. It should be noted that the two words with the most and fewest correct answers in L2 have respectively 6 and 7 letters, which is surprisingly long and may indicate that word length is less important in L2 visual word recognition.

Table 4-2 Correct answers when primed[6] in both experiments

	L1		L2	
Person with the fewest correct answers	12	16 %	14	28 %
Person with the most correct answers	73	97.3 %	43	86 %
Average correct answers per person	60	80 %	32	64 %
Word with the least correct answers	HØVDING	53.23 %	LETTUCE	11.9 %
Word with the most correct answers	SØLV	98.39 %	MONKEY	92.86 %

4.1.4 Mean RTs per word in L1

This thesis is also interested in how fast the participants answer. The results from the L1 experiments will be discussed in this section and those from the L2 experiment in section 4.1.5.

Table 4-3 shows that the five words with the fastest mean RTs are also close to average or above average in terms of the number of correct responses. These words are among the shorter words in the experiment with an average of 4.1 letters per word. The three fastest RTs were also all in the same word condition.

[6] For a complete list of correct answers per word, see appendix.

Table 4-3 The five fastest L1 words

TARGET	Syllables	Letters	Condition	Correct answers	Correct answers in %	Mean RT
PAPIR	2	5	Same	53	85.48 %	580.81
RING	1	4	Same	50	80.65 %	601.18
BENK	1	4	Same	49	79.03 %	602.66
STOL	1	4	Meaning	48	77.42 %	605.77
NATT	1	4	First syllable	50	80.65 %	607.53

Table 4-4 shows the five words with the slowest RTs. These words have two syllables and the average word length is 5.8 letters. Two of the words were primed with unrelated words, two were primed with meaning-related words and one with shared first syllable.

Table 4-4 The five slowest L1 words

TARGET	Syllables	Letters	Condition	Correct answers	Correct answers in %	Mean response time
DROSJE	2	6	Meaning	45	72.58 %	726.20
FLASKE	2	6	Meaning	44	70.97 %	726.67
KLYPE	2	5	First syllable	42	67.74 %	730.59
HØVDING	2	7	Unrelated	33	53.23 %	752.40
VITNE	2	5	Unrelated	40	64.52 %	754.93

4.1.5 Mean RTs per word in L2

As Table 4-5 below shows, the four target words which were answered the fastest were also answered correctly by a high percentage of participants. There also seems to be a trend that those words are short, with an average of 5 letters, and that they are very common words. Three of the words were primed with the same word and one with a shared first syllable. Unexpectedly, the word <RADISH> which has two syllables and was primed with an unrelated word is also among the fastest words. This word was answered correctly by only 10 participants, but all of them must have answered the word quickly.

Table 4-5 The five fastest L2 words

TARGET	Syllables	Letters	Condition	Correct answers	Correct answers in %	Mean RT
VOICE	1	5	Same	33	78.57 %	575.74
NAME	1	4	Same	36	85.71 %	579.64
MONKEY	2	6	First syllable	39	92.86 %	596.66
GOAL	1	4	Same	34	80.95 %	598.09
RADISH	2	6	Unrelated	10	23.81 %	604.14

Table 4-6 below shows that the words with the slowest mean RTs in L2 are generally more unusual. Furthermore, the average word length is 5.8 letters and they are primed either by meaning or unrelated words. All words but one have a low percentage of correct answers. The word that stands out is <PUMPKIN>, which is answered correctly by 83% of the participants, but the mean RT indicates that participants needed a lot of time to respond. None of the other variables, such as word length or condition of priming, indicate why this word should be answered correctly more frequently than the other words.

Table 4-6 The five slowest L2 words

TARGET	Syllables	Letters	Condition	Correct answers	Correct answers in %	Mean RT
LODGE	1	5	Meaning	10	23.81 %	724.86
PUMPKIN	2	6	Unrelated	35	83.33 %	740.98
DOUGH	1	5	Meaning	17	40.48 %	743.26
CHIMNEY	2	7	Unrelated	11	26.19 %	795.49
ROOSTER	2	6	First syllable	15	35.71 %	803.69

4.2 Mean RT by condition

4.2.1 L1 Norwegian

Table 4-7 below shows the mean RTs within each condition in the baseline part of the experiment. In a perfectly designed experiment, all words should be equally difficult and the RTs should therefore be similar. However, Tables 4.7 and 4.8 show that there are significant differences between the conditions. The words used in the *same* and *unrelated* conditions have the highest mean RT and the fewest correct answers. This may indicate that the participants found these words to be more difficult to process. Words were also easier to place in these conditions as they had fewer requirements to fit. The condition *shared last syllable* has the highest number of correct answers and the shortest RT. There is a possibility that these words are easier because it had to be possible to find a suitable prime to the target word with regards to the word length and frequency, in addition to the *shared last syllable*. The same requirements were applied to *shared first syllable* and *shared meaning relations*, which is also reflected in the mean RT and number of correct answers. In total, the number of correct responses is 3679 with an overall mean RT of 645.40.

Table 4-7 L1 Baseline mean RTs by condition

Mean RT baseline RT

Condition	Mean	N	Std. Deviation
Same	655.70	724	126.48
Meaning	639.03	746	126.17
First syllable	648.36	737	132.63
Last syllable	631.59	754	126.89
Unrelated	653.07	718	127.78
Total	645.40	3679	128.26

Table 4-8 L1 ANOVA table to the baseline mean RTs

ANOVA Table

			Sum of Squares	df	Mean Square	F	Sig.
RT_target * Condition	Between Groups	(Combined)	299619.23	4	74904.81	4.571	.001
	Within Groups		60203293.59	3674	16386.31		
	Total		60502912.82	3678			

Table 4-9 shows the mean RT when the target words are primed by a word in the given condition. Overall, the mean RT has increased by 9.27ms and the number of correct answers has increased by 60. Furthermore, the overall standard deviation has increased by 1.02. The *same* condition stands out with a decrease in RT of 30.54ms. The number of correct answers has also increased the most in this condition with 24 more correct answers. However, the standard deviation also increases the most for this condition, which may indicate that *same* word priming decreases the RT in some of the participants, but not in all. The conditions *meaning*, *shared last syllable* and *unrelated* have all experienced an increase in RT as well as in the number of correct answers. *Meaning* has the smallest change in standard deviation, which may suggest that priming with a meaning-related word has little effect on the participants in general. The first syllable and unrelated conditions have both experienced a decrease in standard deviation.

Table 4-9 L1 Primed mean RTs by condition

Condition	Mean	Mean difference	N	N difference	Std. Deviation	Std. Dev. difference
Same	625.16	-30.54	748	24	130.615	4.135
Meaning	665.65	26.62	762	16	126.274	0.102
First syllable	659.11	10.75	732	-5	129.612	-3.021
Last syllable	651.33	19.74	764	10	130.036	3.148
Unrelated	672.92	19.85	733	15	124.802	-2.975
Total	654.77	9.37	3739	60	129.277	1.02

The ANOVA table in Table 4-10 shows that the differences between the conditions are still significant. Indeed, the differences between groups are larger than in the baseline condition, as indicated by the between groups sum of squares. The F-value is the ratio of variance between conditions to variance within conditions. The values of 4.57 and 15.34 for the baseline and primed experiments respectively show how much of the variance can be explained by the condition. For the baseline experiment, the F-value is 4.57, whilst the primed experiment has an F-value of 15.34. This indicates that the condition of the priming has a higher impact on the RT when the target words are in fact primed.

Table 4-10 L1 ANOVA table to the primed mean RTs

ANOVA Table

			Sum of Squares	df	Mean Square	F	Sig.
RT * Condition	Between Groups	(Combined)	1009999.407	4	252499.85	15.340	.000
	Within Groups		61461800.720	3734	16460.04		
	Total		62471800.127	3738			

4.2.2 L2 English

Table 4-11 shows the mean RTs of correct answers for each condition in the baseline part of the experiment as well as mean predicted RTs in baseline. It is clear that although there are some differences between the categories, these are not significantly different according to the ANOVA reported in table 4-12 below. Table 4-11 shows that the category with the most correct answers was those that would be primed by same word in the priming part of the experiment. The unrelated words had the fewest correct answers. However, these conditions also have the slowest RTs in the baseline experiment. As these differences are not significant, the null hypothesis that the participants found them equally difficult to process cannot be rejected. The distribution of words across conditions therefore complies with the experiment design requirements. In total, the number of correct answers is 1320, with an overall mean RT of 656.13ms.

Table 4-11 L2 Baseline mean RTs by condition

Condition	Mean	N	Std. Deviation
Same	668.58	292	125.46
Meaning	642.64	244	132.26
First syllable	658.52	274	133.59
Last syllable	647.26	288	141.84
Unrelated	663.17	222	135.02
Total	656.13	1320	133.85

Table 4-12 L2 ANOVA table to the baseline mean RTs.

ANOVA Table

			Sum of Squares	df	Mean Square	F	Sig.
RT * condition	Between Groups	(Combined)	124875.60	4	31218.900	1.747	.137
	Within Groups		23505641.95	1315	17875.013		
	Total		23630517.56	1319			

Table 4-13 shows the mean RT when the target words were primed by a word in the given condition, as well as the difference to the baseline values. The ANOVA reported in Table 4-14 shows that the results are strongly significant. The F-values, 1.747 in the baseline experiment and 11.322 in the primed experiment, show how much of the variance which can be explained by condition. In L2, the condition of the priming has a high impact on the RT when target words are primed. Table 4-13 shows that the mean RT decreases when primed with the *same* word. However, the mean RT increases when primed with any other condition, as well as having no effect or a negative effect on the number of correct answers. The reference category, the unrelated words, sees a large increase in RT as well as an increase in correct answers. This condition has the slowest mean RT of all conditions, as well as having the fewest correct answers. In total, the standard deviation decreases, indicating that the difference between the slowest and the fastest RTs decreases. This applies to three conditions: *meaning*, *shared last syllable* and *unrelated*. However, *same* word and *shared first syllable* sees an increase in the standard deviation.

Table 4-13 L2 Primed mean RTs by condition

Condition	Mean RT	Mean RT diff.	N	N diff	Std. Deviation	Std. Dev. diff
Same	625.86	-42.72	323	31	136.37	10.91
Meaning	662.58	19.94	244	0	129.64	-2.61
First syllable	668.28	9.76	269	-5	138.84	5.26
Last syllable	656.90	9.64	275	-13	128.41	-13.43
Unrelated	700.75	37.58	232	10	121.56	-13.46
Total	660.32	4.19	1343	23	133.60	-0.25

Table 4-14 L2 ANOVA table to the primed mean RTs

ANOVA Table

			Sum of Squares	df	Mean Square	F	Sig.
RT * condition	Between Groups	(Combined)	784224.49	4	196056.123	11.322	.000
	Within Groups		23170333.57	1338	17317.140		
	Total		23954558.06	1342			

4.3 Linear Mixed Model analysis of RT

The next step is to investigate the effect of the conditions on the RTs by using regression analysis. The following outline and explanation is based upon Winter (2013). A naïve approach to studying the effect of condition on RT would be to use an Ordinary Least Squares (OLS) regression analysis. This would essentially be the same as comparing the mean RTs reported in chapter 4.2. However, an essential assumption in Ordinary Least Squares regression is that residuals are independent and identically distributed. This is clearly not the case in this study because observations are nested within participants as well as within targets. There are multiple observations per participant as well as per word. All the participants responded to several stimuli and the stimuli were presented to all participants. An implication of this is that it is uncertain whether the differences in RT across conditions are caused by different priming conditions or by differences within the stimuli. As discussed in chapter 3.4, there is a difference in word length and presumably in the degree of difficulty between the conditions. It is unknown how much of the difference in RT is caused by unintended known variables, unintended unknown variables or the condition of the prime. This is not unique to this study and while the researcher may take every precaution while preparing the stimuli, it is impossible to create a list of stimuli where all the words are equally difficult. Any number of variables, such as frequency, word length, and orthographic neighborhood are likely to affect the RT of a particular word. No two words will be exactly the same on all these measures. Some words are bound to be easier or harder due to frequency and word length.

Furthermore, it is also unlikely that two participants will have the exact same RT due to their individual differences. Some read generally more slowly while others read more quickly. As discussed in chapter 2.5, reading strategies are individual and depend to a high degree on the development and reading history of the reader. In the analysis of these experiments, only correct answers within a certain range of time are included. Each person will therefore have a unique set of responses which are included in the analysis. As a result of this, each word will also have a unique number of responses, as not all words will be registered with a valid RT. In short, some participants generally answer more slowly or more quickly than the others. Due to this, the mean RT for the set of participants with correct answers for some words will be higher than for others, e.g. in the example of radish above, only a few participants answered correctly, but they were fast. This could be because only the best readers were able to answer correctly for this word, i.e. these may also have had faster RTs for other words.

As a result of these issues, it is necessary to control for both differences between words as well as between participants. This could be done by including fixed effects for words and participants in the model. However, Clark (1973) explains why words cannot be considered a fixed effect and why the results of experiments applying this type of analysis are wrong regardless of the statistical significance of the results. The example he provides is if two researchers are to investigate independently if people read and name nouns or verbs faster. They each find twenty words, nouns and verbs, which they ask 50 subjects to name. However, researcher A may find that his subjects read and name the nouns faster, while researcher B finds that his subjects read and name verbs faster. If enough subjects answer faster in either direction, the findings may be statistically significant in both cases. In fact, both researchers might get significant results supporting their findings. This is possible because the statistical significance is only applicable to the words in the experiment. Between the specific nouns and verbs in the experiment, the results could most likely be reproduced with another 50 subjects. The results can therefore be generalized to the population of subjects, but not to the population of words. Clark (1973) therefore argues that words should be treated as random effects in the same manner that subjects are treated as such. Witzel and Forster (2012: 1612) also discusses why it is better to analyze the results using mixed model effects than the conventional F1.F2 analysis as both subjects and target words may be treated as random effects.

Hence, we need to use the linear mixed model with random effects for subjects and target words. Random effects are used instead of fixed effects when the observed values are considered to have been drawn from a large population to which the findings can be generalized. In a fixed effects model, the interest is in the actual observed values. In the experiments in this thesis, the interest is not if condition of priming has an effect on the exact targets words included in the experiment. Rather, the aim is to investigate if condition of priming has an effect on any word. The actual words included are intended to be representative of a larger population of words in each language. While the words are not randomly drawn from this population, a number of steps have been taken to ensure that they are representative, as outlined above. Hence, we use random effects for words. The same applies to participants: as the aim is to generalize to a larger population of Norwegian 11- and 12-year old children rather than in the individuals included in the study, random effects are used for participants.

This approach would control for any unobserved differences between participants, as well as between words. However, it does not account for any potential interaction between condition and subjects or words. Conditions themselves may have a different effect on different words or on different participants. Hence, it is desirable to account for these differences as well. This can be accomplished by including random slopes. Random slopes allow the effects of the conditions to vary over participants or over words. Unfortunately, both cannot be accounted for at once as the combination of participant and word perfectly identifies each observation. Hence, two models are fitted, one which incorporates random slopes by participant and one by target word. These models are referred to as the session-focused model and the target-focused model, respectively. Both models include random intercepts both for sessions and for targets. Additionally, the session-focused model includes random slopes for conditions across sessions, while the target-focused model includes random slopes for conditions across target words.

4.3.1 L1 Models 1 and 2

The dependent variable in models 1 and 2 in Table 4-15 is the RT from each participant when the target word was primed. This reveals how the RT differs based on which treatment the target word was given. These models include all correct responses in the primed treatment, and the total number of responses is 3739. The RTs are analyzed in two separate operations as the model cannot take into account both how the various words each may have different effects of the priming, i.e. target-focused, as well as how various participants may have different effects of the priming, i.e. session-focused. This provides two separate analyses and Table 4-15 shows the various results in separate models. Model 1 is session-focused while model 2 is target-focused. The session-focused model is generalized to the population of participants whereas the target-focused model is generalized to the corpus from which the stimuli was drawn (Andrews, 1989:806).

The ANOVA in Table 4-15 shows that condition impacts RT significantly in both models. However, the ANOVA does not specify which condition impacts the RT or how. The fixed effects show the mean effect of each condition on the RT. The *unrelated* condition has been set as the reference category, to which all other conditions are compared. In medical terms, this could be considered the placebo treatment which should not have any effect.

Model 1 and 2 in Table 4-15 show that *same* word priming significantly decreases RT with respectively 47.11ms and 50.66ms when the dependent variable is RT of primed responses. The condition *shared last syllable* also significantly decreases RT in both models, but only by 24.19ms and 24.56ms. None of the other conditions experience any effect of priming in L1.

The random effects show the difference between participants and between words. This is important because the condition may have a different effect on different participants as well as on different words. The random effects are the covariances between participants and between words. Condition covariance is how each participant or word responds differently to the condition. If all words and participants responded equally to the condition of the priming, there would be no random effect. The remaining covariance is the residual covariance which cannot be ascribed to condition. However, it is of interest to know much of the covariance in total is due to condition. In order to calculate this, the numbers from condition and residual covariance are added, then the condition covariance is divided by the total. This is the share of the covariance which may be explained by the condition having different effects on participants or target words.

Table 4-15 shows that for models 1 and 2, the share is higher for differences within participants than within words. This means that fewer words have a deviating effect of priming than participants. When the list of stimuli was created, the intention was to make all words as similar as possible and internal differences should therefore be minimal.

Table 4-15 L1 Linear mixed models analysis

	Model 1	Model 2
	RT Session focused	RT Target focused
Fixed effects		
Intercept	674.14*** (7.84)	676.42*** (8.70)
Same	-47.11*** (11.08)	-50.66*** (12.28)
Meaning	-8.84 (11.05)	-9.39 (12.27)
First syllable	-15.90 (11.09)	-16.14 (12.30)
Last syllable	-24.19* (11.07)	-24.56* (12.27)
Unrelated	Reference value	Reference value
ANOVA (condition)	5.27***	4.95***
Random Effects	Subject= session	Subject= target
Residual covariance	13985.74*** (337.90)	15727.55*** (367.54)
Condition covariance	2570.73*** (310.24)	809.45*** (193.22)
Share of covariance accounted for by condition	0.16	0.05
N	3739	3739
BIC	46641.73	46817.24

Note: The numbers in brackets refer to standard errors of the coefficients

*: P < 0.05, **: P < 0.01, ***: P < 0.001

4.3.2 L2 Models 1 and 2

The dependent variable in models 1 and 2 in Table 4-16 is the RT from each participant when the target word was primed. This reveals how RT differs based on which treatment the target word was given. As in the L1 experiment, these models include all correct responses in the primed treatment, and the total number of responses is 1343. Again, the RT is analyzed in two separate operations as the model cannot take into account both how the various words have different effect of the priming, i.e. target-focused, as well as how various participants have different effect of the priming, i.e. session-focused. This provides two separate analyses and Table 4-156 shows the different results in separate models. Model 1 is session-focused while model 2 is target-focused. The session-focused model is generalized to the population of participants whereas the target-focused model is generalized to the corpus from which the stimuli was drawn (Andrews, 1989:806).

The ANOVA in Table 4-16 shows that condition of priming impacts RT in both models. The fixed effects show the mean effect of each condition on the RT. The unrelated prime condition has been set as the reference category, against which all the other conditions are compared. The fixed effects in model 1 show that all conditions have a significant effect on the RT compared to unrelated priming. Same word priming reduces the RT the most, whereas meaning-related and shared last syllable priming have approximately the same effect. Shared first syllable reduces the RT the least. In model 2, only the effects of same word priming and shared last syllable are statistically significant. Both the other conditions reduce the RT, but these findings are not significant.

The random effects show the difference between participants and between words. This is important because the condition may have a different effect on different participants as well as on different words. The random effects are the covariance between participants and between words. Condition covariance is how each participant or word responds differently to the condition. If all words and participants responded equally to the condition of the priming, there would be no random effect. The remaining covariance is the residual covariance which cannot be ascribed to condition. Once more, it is of interest to know much of the covariance in total is due to condition. In order to calculate this, the numbers from condition and residual covariance are added, and the condition covariance is divided by the total. This is the share of the covariance which may be explained by the condition having different effects on participants or target words. Table 4-16 shows that the share of covariance that can be explained by condition is larger in model 1 than in model 2.

Table 4-16 L2 Linear mixed model analysis

	Model 1	Model 2
	RT Session focused	RT Target focused
Fixed effects		
Intercept	701.83*** (11.56)	699.86*** (13.32)
Same	-73.49*** (15.78)	-72.40*** (18.06)
Meaning	-38.22* (16.26)	-32.21 (18.81)
First syllable	-31.79* (16.10)	-26.12 (18.44)
Last syllable	-42.05** (16.04)	-40.83* (18.37)
Unrelated	Reference value	Reference value
ANOVA (condition)	5.54***	4.26**
Random Effects		
Covariance residual	14548,54*** (610.41)	16497.52*** (649.67)
Covariance between conditions	2856.49*** (526.15)	971.38** (361.51)
Share of covariance accounted for by condition	0.16	0.06
N	1343	1343
BIC	16827.83	16873.97

Note: The numbers in brackets refer to standard errors of the coefficients

*: P < 0.05, **: P < 0.01, ***: P < 0.001

4.4 Linear Mixed Model analysis baseline adjusted

Witzel and Forster (2012: 1617) note that there may be a difference between generally slow readers and fast readers, and that this may affect the mean RTs used in the previous analysis. They attempt to minimize the effect of this by dividing the participants into two groups, the slower readers and the faster readers. They report that there was no interaction between the two groups in their experiments.

Similarly to Witzel and Forster (2012) the models in this thesis, reported in chapter 4.3, use only data from the primed part of the experiments. That is, the data used is the actual RT when the target word is preceded by a prime word. However, the experiments also included a baseline value for each word. The target words in the baseline part of the experiment were not primed. Consequently, each participant-word combination is observed twice, once in the baseline treatment and once in the primed treatment. The RTs from the baseline treatment may therefore provide additional information which may shed light on how each individual's RT changed when the target word was primed compared to the unprimed baseline treatment.

In chapter 4.2, the mean RTs by primed conditions were compared with baseline RT. The baseline RTs were not affected by priming yet. However, the words were categorized by the condition of the prime it would receive in the other half of the experiment. For both languages, the comparison of the mean values showed that only same word priming seemed to have an excitatory effect on the RT. The other conditions seemed to have an inhibitory effect on the RT of the target word.

The exact RT in baseline for a specific word by a certain subject must be considered as a single observation which the subject most likely will not be able to recreate. Due to random variation, the RT will vary between multiple observations even if it is the same subject responding to the same word several times. This is a stochastic effect. If one subject did respond to the same word every day for ten days and thereby provided ten unique RTs, this would also include a learning effect as the subject would most likely improve due to practice. However, in this case, each word is only included twice, once in the baseline and once in the primed treatment. An individual observation may, from a statistical point of view, be considered to be drawn from a larger population of possible RTs. The distribution of RTs in this population will be a function of the participant and of the word. Hence, the probability of drawing an observation with a certain RT is a function of the frequency of the RT in this underlying population, but there will be a stochastic element to the actual RT observed in the experiment.

Outliers in this distribution would be incorrect answers and RTs faster than 345ms or slower than 1000ms, as described in chapter 4.1.1. These outliers have been excluded from the analysis. The aim is to investigate the mean values of the observations within a participant, and by excluding the outliers, there is less variation between the observations provided by a participant. Although this reduces the variation, there will still be a stochastic element.

To reduce the stochastic element, the following procedure has been applied: Rather than comparing the primed responses with the equivalent baseline responses for the same participant and target word, the primed responses have been compared with a predicted RT for each participant-word combination. The predicted RT is based on all responses by the particular participant and all responses for the target word in baseline. This was done by estimating a linear mixed model where the dependent variable is the baseline RT, which is modeled as a function of random effects of participants and target words. This makes it possible to estimate a predicted unprimed RT for all observations, to which the primed observations can be compared. The predicted RTs contains information about the difficulty of the words based upon the actual RTs from all participants, as well as the variety in reading speed among all participants based upon how quickly they responded to all words. The predicted RTs reduce the stochastic element and random variation because they are based upon several observations per target word as well as several observations per participant.

For L1 the mean RT is 645.40 for both the actual baseline RTs and the predicted RT as shown in Table 4-17. However, the standard deviation for actual RTs is 128.26 whilst for the predicted RT, this has been reduced to 71.02. For L2, Table 4-18 shows that the mean RT is 656.13 for both the actual baseline RTs and the predicted RT. However, the standard deviation for actual RTs is 133.85 whilst for the predicted RT, this has been reduced to 73.26. This shows that there is less variation within the predicted RTs because the random component has been reduced through the use of several observations for each predicted RT.

Table 4-17 L1 Mean predicted baseline RT

Condition	Mean	N	Std. Deviation
Same	655,70	724	70,96
Meaning	639,03	746	71,31
First syllable	648,36	737	69,87
Last syllable	631,59	754	66,35
Unrelated	653,075	718	73,91
Total	645,40	3679	71,02

Table 4-18 L2 Mean predicted baseline RT

L2 Mean predicted baseline RT

Condition	Mean	N	Std. Deviation
Same	668.58	292	70.41
Meaning	642.64	244	71.35
First syllable	658.52	274	73.07
Last syllable	647.26	288	76.45
Unrelated	663.17	222	71.78
Total	656.13	1320	73.26

Furthermore, the comparison between baseline and primed responses only include words where the participant has answered correctly in both parts of the experiment. If the participant responded incorrectly in the baseline part of the experiment, or in the primed part, or the RT was excluded due to the reasons mentioned above, it was not possible to calculate the difference between the two RTs. Another consequence of this is that if the priming caused correct responses where the baseline response was incorrect, these observations are not included because the lack of a baseline RT makes it impossible to calculate a difference between the two.

In the following analysis, the dependent variable is the difference between the actual primed RT and the predicted baseline RT. There are fewer observations in these analyses because it was not possible to predict RTs for observation that were missing in baseline.

4.4.1 L1 Model 3 and 4: Baseline adjusted RT

In Table 4-19, there are two models, which are referred to as models 3 and 4. The difference between them is the same as the difference between models 1 and 2 in chapter 4.3. Model 3 is session-focused and model 4 is target-focused.

The ANOVA for models 3 and 4 in Table 4-19 shows that only model 3 achieve significant results, and the fixed effects show that the condition which has a significant effect of priming is the *shared last syllable*. None of the other conditions have a significant effect on the baseline adjusted RT. It is interesting to note that Table 4-19 shows that when baseline adjusted RTs are taken into consideration, not even *same* word priming has any effect despite the strong significance found in models 1 and 2 for this condition. In models 3 and 4 same word priming appears to slow down the baseline adjusted RT in both models. Although these numbers are not statistically significant, this may indicate that seeing a word repeatedly may even confuse the children. However, *meaning* priming may have an excitatory effect although these numbers do not reach statistical significance (although they are significant at the 90% level).

The share of condition covariance calculated in model 4 is the highest across all four models. This indicates that the condition of priming can explain more of the covariance when the dependent variable is baseline adjusted RT and the random effect analysis is focused on the target word. The purpose of calculating the baseline adjusted RT was to filter out as much as possible of the covariance caused by individual differences.

Table 4-19 L1 Linear mixed models analysis baseline adjusted RT

	Model 3	Model 4
	baseline adjusted RT Session focused	baseline adjusted RT Target focused
Fixed effects		
Intercept	646.55*** (4.25)	653.95*** (9.43)
Same	7.77 (6.00)	3.64 (13.33)
Meaning	-10.18 (5.98)	-12.47 (13.31)
First syllable	1.09 (5.99)	-3.46 (13.32)
Last syllable	-14.36* (5.96)	-22.29 (13.31)
Unrelated	Reference value	Reference value
ANOVA (condition)	4.54***	1.24
Random Effects	Subject= session	Subject= target
Residual covariance	4107.54*** (110.54)	3695.05*** (95.65)
Condition covariance	649.90*** (88.62)	1234.85*** (226.60)
Share of covariance accounted for by condition	0.14	0.25
N	3061	3061
BIC	34428.03	34011.69

Note: The numbers in brackets refer to standard errors of the coefficients

*: P < 0.05, **: P < 0.01, ***: P < 0.001

4.4.2 L2 Model 3 and 4 baseline adjusted RT

In Table 4-20, there are two models which are referred to as models 3 and 4. The difference between them is the same as the difference between models 1 and 2 in chapter 4.3. Model 3 is session-focused and model 4 is target-focused.

The ANOVA for models 3 and 4 in Table 4-20 shows that both models have significant results. In both models 3 and 4, same word priming has the strongest effect and reduces the baseline adjusted RT the most. Shared first or last syllable reduces the baseline adjusted RT with the same amount and the significance level is the same. Meaning-related priming does not have significant effect on the baseline adjusted RT.

The share of condition covariance calculated in model 4 is the lowest across all four models. This indicates that differences in the effects of priming condition can explain very little of the covariance when the dependent variable is baseline adjusted RT and the random effect analysis is focused on the target word. The purpose of calculating the baseline adjusted RT was to filter out as much as possible of the covariance caused by individual differences. Model 4 shows that when those measures have been taken, a very small share of covariance is accounted for by condition.

Table 4-20 L2 Linear mixed model analysis baseline adjusted RT

	Model 3	Model 4
	Baseline adjusted RT Session focused	Baseline adjusted RT Target focused
Fixed effects		
Intercept	41.24*** (12.22)	41.37*** (11.01)
Same	-91.37*** (16.28)	-92.99*** (14.26)
Meaning	-19.19 (16.95)	-17.67 (15.13)
First syllable	-35.89* (16.80)	-38.35* (14.87)
Last syllable	-36.48* (16.60)	-35.97* (14.65)
Unrelated	Reference value	Reference value
ANOVA (condition)	9.22***	13.05***
Random Effects		
Covariance residual	15598.77*** (782.12)	17342.22*** (794.05)
Covariance between conditions	1900.89*** (556.54)	99.54 (190.61)
Share of covariance accounted for by condition	0.11	0.01
N	994	994
BIC	12485.34	12505.11

Note: The numbers in brackets refer to standard errors of the coefficients

*: $P < 0.05$, **: $P < 0.01$, ***: $P < 0.001$

4.5 Summary

This section aims to summarize the findings in the previous analyses and highlight the differences and similarities across languages when appropriate.

4.5.1 Correct vs incorrect

As Table 4-2 in section 4.1.3 shows, there are big differences between the participants as well as between the words in terms of the share of correct answers. The average share of correct answers per person is much higher in L1 than in L2, but the variation between participants is smaller in L2 than in L1.

4.5.2 Top and bottom five

All but one of the words in top five for speed have a high percentage of correct answers. That the fastest words are also answered correctly by most participants is reassuring, as this indicates that fast answers are not a result of guessing and random answers. The one word which stands out is from the L2 experiment, which only 23% participants answered correctly. With a 50/50 chance of getting it right by responding at random, 23% correct answers combined with fast responses could indicate that the responses may have been random. Although measures have been taken to avoid including such responses, there is a possibility that valid responses are excluded by them, and that invalid responses are nonetheless included. This is one of the disadvantages of quantitative studies. Due to the vast amount of observations, it is impossible to qualify each observation. However, the statistical analyses take this into account. The results further show that in both experiments, 3 of the 5 fastest words were primed with the same word. Both experiments also see a word primed with a shared first syllable on this list. In L1, the word with the least correct answers of the top five fastest was primed with a meaning-related word. In L2 the word with the least correct answers of the top five fastest was primed with an unrelated word.

The slowest words generally have a lower correct response percentage than the fast words. In the L1 experiment, all of the slowest words are slower than the average 80%

correct responses, however all are higher than the 50% predicted by random guessing. In the L2 experiment, though, only one of the five slowest words has a high percentage of correct responses. The remaining four words see percentages between 23 and 40%. Given the previous argument that percentages lower than 50 are possible guesses, it is reasonable to assume that this applies to these words as well.

In the L1 experiment, two words were primed with meaning, two were unrelated and one with shared first syllable. The words primed with unrelated words were the slowest and had the lowest percentage of correct answers of these five words. Nevertheless, the unrelated condition is the reference category, which is not intended to have any effect on how the participant reacts to the target word. Table 7.1 in the appendix shows that if the unrelated words were excluded from the bottom five, the priming conditions would be four meaning-related word pairs and one with a shared first syllable.

In the L2 experiment, two words were primed with meaning, two were unrelated and one with a shared first syllable. If the unrelated word pairs are removed, there would be two meaning-related pairs, two pairs with shared first syllable and one pair with shared last syllable among the five slowest word pairs. Compared with the results in the L1 experiment, these numbers are less clear.

4.5.3 Mean RTs

In both L1 and L2 experiments the mean RTs were analyzed by condition, for both baseline RTs and primed RTs. The condition of the baseline RT is not relevant because the baseline RTs are only included to provide information about the expected RT for a target word in a normal state. A comparison of the two experiments show that in baseline the conditions *same word*, *shared first syllable* and *unrelated* in both experiments see mean RTs slower than the mean value for all words. The conditions *meaning* and *shared last syllable* see faster mean RTs. If RT is an indication of how difficult it is to recognize, this is an indication that even if some words may be more difficult to recognize, the pattern of difficulty is similar across languages. As discussed in section 3.4, compiling the perfect list of stimuli where all words are equal is as unlikely as finding multiple participants who respond equally.

In both experiments, the overall mean RT is higher when the target word is primed compared with the baseline RTs. This is the case for all conditions except for *same word* priming, where the mean RT decreases. In the L1 experiment, all conditions except *shared first syllable* exhibit an increase in correct responses, but in L2, only *same word* and *unrelated* exhibit an increase in correct responses. *Meaning*-related is unchanged whilst *shared first* and *shared last syllable* exhibit a decrease in correct responses as well as an increase in RT.

4.5.4 Linear mixed models

Tables 4-15 and 4-16 both show the linear mixed model analysis for L1 and L2, respectively. The ANOVAs for both experiments show that all models have significant results. However, not all conditions are significant. In both experiments, and in all models, *same word* priming is strongly significant and causes a decrease in RT.

Other conditions which experience a significant priming effect in both experiments and all models are *shared last syllable*. However, only in the L2 experiment in the session-focused model does all conditions have a significant effect on the lexical decision task compared to unrelated priming.

The share of covariance accounted for by condition is similar across both experiments and the difference between the models is quite similar across both experiments. In both experiments, the share of covariance is higher in the session-focused models than in the target-focused models. This means that in both experiments the internal differences within participants which cause them to react differently to the condition of the stimuli is higher than the internal differences within target words.

4.5.5 Linear mixed models baseline adjusted

Tables 4-18 and 4-20 both show the linear mixed model analysis for respectively L1 and L2 when the RTs have been adjusted for expected RTs based on observations in the baseline treatment.

The ANOVAs for both experiments show that all models but one have significant results. In the L1 experiment, *same word* priming does not exhibit a significant effect of priming, whereas in L2, *same word* priming has a strong effect.

In L1, only the session-focused model has a significant effect for *shared last syllable*. None of the other conditions exhibit an effect in L1. In both models in L2, all conditions except meaning have an effect on the RT.

For L1, the residual covariance was reduced drastically from models 1 and 2 to models 3 and 4, meaning that by comparing the RT with the baseline-adjusted RT, so much of the disturbing factors were excluded from the analysis that the small changes in RT became statistically insignificant. However, the insignificant results show that meaning and shared last syllable decreases RT in the session-focused model, whilst in the target-focused model, all conditions except same word priming decreases RT. In both models, same word priming results in a slight and insignificant increase in RT.

The share of covariance accounted for by condition in L2 in the session focused models are 0.16 and 0.11 and in the target focused session they are 0.06 and 0.01. The internal difference is higher within the participants than within target words. Likewise, in L1, the share of covariance is similar in size to the session-focused model in the previous analysis. However, in the target-focused model when analyzing the baseline adjusted RT, the share of covariance which is accounted for by condition is the highest overall. Seen in the light of the size of the residual covariance, the L1 target-focused model is much smaller than in L2 despite a higher number of observations in L1 than in L2.

4.5.6 Inconsistencies and conclusions

As the previous sections illustrate, it does matter how quantitative data is analyzed and it is easy to jump to the wrong conclusion by focusing on only one of the tables above. Of the two versions of the mixed model analysis, the baseline-adjusted RT (models 3 and 4) are most likely the most accurate reflections of what is going on, as these models eliminate most of the unknown confounding factors. In addition to the advanced analysis, the descriptive statistics in chapter 4.1 will function as explanations of why the results in the more advanced analyses are what they are.

5 Analysis

The two hypotheses introduced in chapter 1 proposed that:

H_0: Word-to-word priming of related words does not affect RTs in children

H_1: Word-to-word priming of related words does affect RTs in children

The results for these hypotheses are less straightforward than a simple yes or no, but as the findings presented in the previous chapter showed, there are good reasons to believe that word-to-word priming of related words does affect RTs in children both in L1 and in L2. Most of the analyses are in favor of a clear yes, except in L1 where the analysis in model 4 (target-focused model) which exhibits no significant effects. This gives a clearer answer to the second hypothesis:

H_0: The priming effect is the same in L1 and L2.

H_2: The priming effect is different in L1 and L2.

The priming effect is different in L1 than in L2. However, the effect is stronger in L2 than in L1, which is the opposite of the assumptions implied in the introduction. The starting-point for the analysis was that priming has been found in earlier studies to have an effect in adults, which this in turn led to the question: is the same effect present in younger readers?

There are several perspectives to consider in the following discussion of the findings. The structure of the discussion follows the structure of the literature review. First, the findings will be discussed in light of the theories about the mental lexicon presented in chapter 2.1. Second, the findings will be discussed in light of theories from the opposite perspective, from a teaching point of view presented in chapter 2.5. Third, the analyses of the findings will be discussed with regards to the methodological issues put forward in chapter 2.3.

5.1 In light of the theories from psycholinguistics

The literature review presented the two main approaches to the mental lexicon. The first is constructed to understand how people process writing and visual word recognition. It builds upon Interactive Activation (McClelland and Rumelhart, 1981) and results in the Dual Route Cascade (Coltheart et al. 2001). The idea is that a person will decode the stimuli by recognizing words which are connected to letters which again are connected to phonemes and then the person can say the word aloud. The PDP model (Seidenberg, 2005) is similar to the DCR model but it relies less on the strict phoneme – letter – word hierarchy. Instead, it emphasizes the distribution of the activation to all the nodes which are not necessarily organized by level and that the link between these nodes go both ways. Furthermore, the PDP model as well as the connectionist approach emphasize that the person who uses the language will learn and develop the mental structures which support language processing (Seidenberg, 2005, Seidenberg, 2012). A possible interpretation of these models, and in particular the PDP model, is that the brain will adapt to how it is trained to recognize or decode words and later to read for meaning. The findings in this thesis may be seen as support either for the proposition that the brain develops in phases or in favor of the assumption that teaching method matters the most until a certain level of proficiency is reached. The learning aspect of the findings will be discussed in section 5.2.

The other model, WEAVER++ (Levelt 2001, Roelofs, 1997 and 2000), assumes that there is a link between the lemmas which may cause activation of semantically related lemmas. The assumption is that if there is a link between the lemmas, activating one lemma will have an excitatory effect on the linked lemmas. Only model 1 in L2 (session-focused RT), showed a significant effect for *meaning*. None of the other models showed a significant effect for priming with a semantically related word. In L1 model 3 suggests a trend towards an excitatory effect for meaning priming.

Furthermore, as mentioned in chapter 2.1.7, Roelofs (2000) predicted an excitatory priming effect for first-syllable and second-syllable. However, as some of the words in this thesis consist of two syllables, the second syllable will be the last syllable. The analyses of L1 in chapter 4.4 partially support Roelofs' (2000) prediction. Only the subject focused model (model 3) exhibit significant excitatory effect for form priming with *shared last syllable*. For L2, the analyses shown in models 3 and 4 do support this, as they exhibit a decrease in RT when primed with these condition.

5.2 In light of literacy theories

As suggested in chapter 2.5 and 2.6, it seems as though visual word recognition is linked to how reading in the target language is taught. Norwegian is usually taught through the phonological route. However, as the teacher's book and online exercises from *Stairs* show, this idea is not transferred to literacy instruction in English as L2 in Norway. Rather, English language teaching in Norwegian schools relies on the dual route approach with the aid of L1 phonological knowledge. Therefore, in order to properly investigate if the differences between the effect of priming in L1 and L2 are structural differences or instructional consequences, it would be necessary to compare results between groups who have had the same type of instruction in both languages.

Whereas Norwegian students have most likely been taught how to read through the phonological route, which may be why there is only significant effect for *shared last syllable*. This may also be an indication that they are in a between-phase, in which they might still rely on orthographic features as well as meaning. The data did not allow for any firm conclusions.

Levelt (1989) put forward the idea that a lexical entry consists of four equal features: meaning, syntax, morpheme and phoneme. Although the statistical analyses in chapter 4.4 do not support Levelt's ideas of closely linked lemmas in either language, this may be explained by other circumstances. For L1 there is an indication that meaning might have a facilitory effect, but there is also a possibility that the words chosen for the meaning-related priming condition just did not have sufficiently strong meaning relations from the children's point of view. However, for L2, the picture is quite different as all priming conditions that rely completely or partially on form similarity exhibit strong effects from priming. This can be seen as a strong indicator that the children do not rely on meaning when they encounter English words. From a teaching point of view, this indicates that when the students "read" English, they do not necessarily read for meaning. They might read on a mere technical level, almost like the computational models designed by Coltheart et al. (2001) and Roelofs (1997).

5.3 In light of the methodological issues

In this section a few, but quite different methodological and analytical issues will be discussed.

The unknown variables: The main methodological issue put forward in chapter 2.3 by Cattell (1886a) is that there are an unknown number of unknown variables present when studying mental processes. The researcher can only to a certain degree attempt to eliminate or diminish assumed variables which may have a disturbing effect. The analyses of the data in this thesis has used linear mixed model analysis as this is considered the best method to ensure that unknown variables does not cause the findings to be misrepresented. As the two sets of models (1+2 and 3+4) show, it is important to apply the appropriate methods for analysis.

Children as subjects: In chapter 2.3.2 it was suggested that this thesis could contribute to the literature as this is one of the few studies who have successfully used lexical decision tasks with word-to-word priming in children. The strong results found especially in the L2 experiment demonstrate that 12-year-old children have an effect of priming when the primer is shown for 100ms. They are also capable of responding within the time frame used in these experiments. The residual covariance may be an indication that children read better in Norwegian and that all children are more familiar with the Norwegian words. This claim can also be supported by the descriptive statistics in section 4.1.3. The table shows that the L1 experiment also had an overall higher percentage of correct answers per participant than the L2 experiment.

Choice of task: The tasks used may also favor certain effects, Andrews (1991) found that the effect for orthographic neighborhoods was stronger in lexical decision tasks than in naming tasks. However, Andrews (1992) found that phonological consistency influences naming tasks more strongly than lexical decision tasks. However, the experiments in this thesis show that the students benefit from orthographic similarity in lexical decision tasks.

Compiling list of stimuli: It seems impossible to check for multiple features in one experiment due to the possibility of cross-contamination between the words.
It is therefore necessary to perform multiple experiments with separate groups of participants.

5.4 Room for improvement

The word lists were created by an adult, and especially the meaning relation between the words may have been weaker for the children. This could be further investigated by asking children to compile lists of words which they think of as meaning related. As the results from L1 are ambiguous on both form and meaning, this is a field that is still open for further research. Regarding the L2 data, these appear to be quite strong, but it would be interesting to compare these findings to students who have had more focus on learning to read through the phonetical route, and to a group of students whose first language is English. The latter experiment would shed light on whether the ambiguous results from L1 are representative across languages and reading strategies.

6 Conclusion

This thesis set out to investigate if word-to-word priming has an effect on young readers in their first and second language. The second chapter discussed relevant theories regarding lexical access. The theory section goes through the historical development and the major contributors to research on the mental lexicon, and to our understanding of how the brain processes language.

The theoretical starting point was as early as the 19th century with Cattell (1886a and b), however the early models were developed in the 1960s. In the early days the great divide was between Morton's (1969) Logogen Model and Forster's Search Model (Warren, 2012). Both models have since been developed further, but it is the Logogen Model which have been the inspiration for later models such as the Interactive Activation model (McClelland and Rumelhart, 1981) and the more recent Parallel Distribution Processing (Seidenberg, 2012). These represent the connectionist approach which focus on how the brain learns and builds its structure as it is exposed to language. The opposite approach is the cognitivist approach which assumes that the structure of the brain is constant. This approach is represented by Coltheart et al. (2001) and the Dual Route Cascade model. A third approach is represented in this thesis by Levelt (1989, 2001) and WEAVER++ (Roelofs, 1997, 2000). These are accompanied by Dell (1986) who once was a branch of the Logogen and IA models.

Based upon these theories, one can expect that words with the same form (e.g. in the PDP model) and/ or with the same meaning (e.g. in Levelt) will be linked in the mental lexicon. These ideas are probed in an experiment, testing the effect of priming with form-related, meaning-related or both, on the speed of lexical decision making in a group of 12-year-old Norwegian children. Children are tested twice, once in their first language (Norwegian) and once in their second language (English) in order to examine whether any of these word relationships have an excitatory or inhibitory effect in L1 and L2.

The two experiments were run in two elementary schools in the city of Stavanger, Norway, and were conducted five months apart. The L1 experiment had 62 participants while the L2 experiment had 42 participants (only one school participated). The participants solved 150 lexical decision tasks in L1 and 100 lexical decision tasks in L2. Each task was solved twice, once with a prime and once unprimed. Primes could be related to the target word either in form, meaning or both, or they could be unrelated. 50% of the tasks were pseudo-words primed with an unrelated real word.

The results showed a significant reduction in response times in same-word priming and form-related priming in L2. In L1, the results for priming were weaker, and only one type of form-related priming significantly reduced response times in the model that takes expected response times based on baseline responses into account. This supports mainly the PDP model, especially in L2. There are few indications in the data that meaning-related primes has an excitatory effect on lexical decision making tasks in 12-year-old Norwegian children as suggested by Levelt (1989, 2001).

This thesis has provided new knowledge on the effect of priming on lexical decision making in children which is an area which has received very little attention in previous research. The thesis also covers both first and second language learners, finding somewhat different patterns for L1 and L2, which is again an understudied area. While further research is needed to understand how children recognize words, this thesis has been a first attempt at applying lexical decision making tasks and priming to the study of children. In this way, it has made a contribution to the understanding of how children process words.

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8 Appendices

8.1 Consent forms

Forespørsel om deltakelse i forskningsprosjektet "Skriveuke"

Til elev og foresatte.

Vi vil invitere deg/ditt barn til å delta i et prosjekt om skriving hvor vi undersøker situasjoner som kan påvirke selve skrivingen. Vi prøver å finne ut når det er naturlig for skrivere å ta pause og hva som ser ut til å være utfordrende når de skriver. I tillegg ønsker vi å identifisere faktorer som kan fremme god flyt i tekstproduksjon. Dette gjør vi for at vi i neste omgang kan lage bedre verktøy for skrivestøtte. Prosjektet inngår en del av en doktorgradsstudie ved UiB/UiS.

Hele klassen til barnet ditt er invitert til å være med, på en «Skriveuke». De elevene som takker nei til å være med vil jobbe med de samme tingene som resten av klassen, men tekstene deres vil ikke bli gitt til oss. Elevenes identitet er ikke kjent for oss før dere krysser av og signerer på at dere vil delta. I tillegg ber vi om tillatelse til at skolen oppgir elevens resultat på nasjonale prøver fra 5.trinn.

Hva innebærer deltakelse i studien?
I selve studien vil vi at elevene skal skrive fire korte tekster i forskjellige situasjoner, de skal og gjennomføre en orddelingsoppgave, en staveoppgave, en undersøkelse av håndskrifts og keyboard ferdighet, en oppgave som handler om å gjenkjenne mønster og en navngivningsoppgave. Skriveoppgavene, staveoppgaven og mønsteroppgaven gjøres sammen med resten av klassen. Resten skjer individuelt. Vi legger hele tiden vekt på at elevene skal oppleve mestring og ha positive opplevelser knyttet til skriving.

Hva skjer med informasjonen om eleven?
Alle personopplysninger vil bli behandlet konfidensielt. Når vi skal studere selve skrivingen, vil også en forsker ved Universitetet i Bergen delta. Forskerne som er med i prosjektet har taushetsplikt når det gjelder opplysninger fra studien. Undersøkelsen er avklart med og i tråd med retningslinjene fra personvernombudet for forskning, Norsk samfunnsvitenskapelig datatjeneste (NSD).

Prosjektet skal etter planen avsluttes 01.07.2015. Datamaterialet anonymiseres ved prosjektslutt.

Frivillig deltakelse
Vi understreker at det er frivillig å delta i studien, og en kan når som helst trekke samtykke, uten å oppgi noen grunn. Dersom en trekker seg, vil alle opplysninger bli slettet. Det vil ikke få noen konsekvenser i forhold til skolen om man ikke velger å delta.

Dersom har spørsmål til studien, ta kontakt med Vibeke Rønneberg vibeke.ronneberg@uis.no eller på telefon 90042611.

Studien er meldt til Personvernombudet for forskning, Norsk samfunnsvitenskapelig datatjeneste AS.

Samtykke til deltakelse i studien

☐ Jeg har mottatt informasjon om studien fra skolen, og samtykker i at mitt barn kan delta i studien.
Barnets navn:______________________

Foresattes signatur: ______________________

Forespørsel om deltakelse i mastergradsprosjekt om ordgjenkjenning hos barn

Til elev og foresatte.
Våren 2015 ble du/ditt barn invitert til å delta i et prosjekt om skriving hvor vi undersøkte situasjoner som kan påvirke selve skrivingen. Dette prosjektet er en forlengelse av den skriveuken elevene da deltok i. Hensikten med denne studien er å undersøke hvordan barna umiddelbart gjenkjenner engelske ord de blir eksponert for. Elevene vil bli bedt om å gjennomføre en test på data som tar cirka 10 minutter. Deretter vil de få en vokabulartest for å dokumentere forståelse av engelske ord.

De elevene som takker nei til å være med, vil få tilbud om å ta testen sammen med de andre elevene, men resultatene deres vil bli forkastet. Elevenes identitet er ikke kjent for oss før dere krysser av og signerer på at dere vil delta.

Resultatene i denne studien vil kobles sammen med resultatene fra forskningsprosjektet «skriveuke», ledet av Vibeke Rønneberg ved UiS.

Hva skjer med informasjonen om eleven?
Alle personopplysninger vil bli behandlet konfidensielt. Forskerne som er med i prosjektet, har taushetsplikt når det gjelder opplysninger fra studien. Undersøkelsen er avklart med og i tråd med retningslinjene fra personvernombudet for forskning, Norsk samfunnsvitenskapelig datatjeneste (NSD).

Prosjektet skal etter planen avsluttes oktober 2015. Datamaterialet anonymiseres ved prosjektslutt.

Frivillig deltakelse
Vi understreker at det er frivillig å delta i studien, og en kan når som helst trekke samtykke, uten å oppgi noen grunn. Dersom en trekker seg, vil alle opplysninger bli slettet. Det vil ikke få noen konsekvenser for ditt forhold til skolen om du velger ikke å delta.

Dersom du/dere har spørsmål til studien, ta kontakt med Camilla Lausund Fitjar cl.fitjar@stud.uis.no eller på telefon 97729516.

Studien er meldt til Personvernombudet for forskning, Norsk samfunnsvitenskapelig datatjeneste AS.

Samtykke til deltakelse i studien

☐ Jeg har mottatt informasjon om studien fra skolen, og samtykker i at mitt barn kan delta i studien.

Barnets navn:____________________

Foresattes signatur: ______________________

8.2 Norwegian stimuli with English translation

Table 8-1 Norwegian real word-pairs with translation

Condition	Prime	translation	TARGET	translation
same	agent	agent	AGENT	
same	kikkert	Binoculars	KIKKERT	
same	eske	Box	ESKE	
same	stang	Pole	STANG	
same	papir	Paper	PAPIR	
same	stein	Stone	STEIN	
same	skygge	Shadow	SKYGGE	
same	fjell	Mountain	FJELL	
same	kurv	Basket	KURV	
same	benk	Bench	BENK	
same	ring	Ring	RING	
same	kule	Bullet	KULE	
same	piano	Piano	PIANO	
same	diamant	Diamond	DIAMANT	
same	telefon	Telephone	TELEFON	
meaning	arm	Arm	BEIN	Leg
meaning	maleri	Painting	BILDE	Picture
meaning	linser	Lenses	BRILLER	Glasses
meaning	sang	Song	DIKT	Poem
meaning	bil	Car	DROSJE	Taxi
meaning	selskap	Company	FEST	Party
meaning	tommel	Thumb	FINGER	Finger
meaning	vegg	Wall	GULV	Floor
meaning	bord	Table	STOL	Chair
meaning	beholder	Container	FLASKE	Bottle
meaning	bjørn	Bear	ULV	Woolf
meaning	fane	Banner	FLAGG	Flag
meaning	sjekk	Check	KONTROLL	Controll
meaning	jord	Earth	GRUS	Gravel
meaning	hylle	shelf	SKAP	Cupboard
Last syllable	krutt	Gunpowder	GUTT	Boy
Last syllable	kode	Code	HODE	Head
Last syllable	pant	Deposit	KANT	Edge
Last syllable	masse	Substance	KLASSE	Class
Last syllable	trappa	Stairs	PAPPA	Dad
Last syllable	gull	Gold	HULL	Hole
Last syllable	fart	speed	KART	Map
Last syllable	test	test	HEST	Horse

Last syllable	krampe	Crampe	LAMPE	Lamp
Last syllable	plass	Place	GLASS	Glass
Last syllable	spytt	Saliva	PYTT	Puddle
Last syllable	hekk	Hedge	SEKK	Bag
Last syllable	bevis	Evidence	AVIS	Newspaper
Last syllable	bror	Brother	SPOR	Trace
Last syllable	havn	Dock	NAVN	Name
First syllable	ansatt	employee	ANKEL	Ankle
First syllable	napp	Bite	NATT	Night
First syllable	flom	Flood	FLOKK	Flock
First syllable	pass	Passport	PARK	Park
First syllable	klynge	Group	KLYPE	Clip
First syllable	lam	Lamb	LAPP	Note
First syllable	laser	Laser	LAGER	Storage
First syllable	pels	Fur	PENN	Pen
First syllable	skilt	Sign	SKIP	Ship
First syllable	hare	Hare	HAGE	Garden
First syllable	dame	Woman	DATO	Dato
First syllable	vinkel	Angle	VINDU	Window
First syllable	fisk	Fish	FILM	Film
First syllable	pest	Plague	PEIS	Fireplace
First syllable	leke	toy	LEGE	Doctor
unrelated	bukse	Pants	PISTOL	Gun
unrelated	pute	Pillow	NESE	Nose
unrelated	skjorte	Shirt	SOPP	Mushroom
unrelated	torsk	Cod	SKOLE	School
unrelated	slips	Neck-tie	SOFA	Sofa
unrelated	modell	Model	SPILL	Game
unrelated	kjole	Dress	SPORT	Sport
unrelated	ramme	Frame	SVETTE	Sweat
unrelated	koffert	Suitcase	SANGER	Songs
unrelated	nøkkel	Key	MALING	Paint
unrelated	kontor	Office	SØLV	Silver
unrelated	maske	Mask	SKØYTER	Skates
unrelated	blyant	Pencil	HØVDING	Chief
unrelated	spade	Spade	SLIM	Slime
unrelated	hummer	Lobster	VITNE	Witness

Table 8-2 Norwegian pseudo-words

TARGET	prime	TARGET	prime	TARGET	prime
HØPTE	armbånd	KLURME	knekt	MORREK	kjøtt
KANEM	aske	KROPJU	alkohol	ISUT	seminar
MORKA	bakke	GUMB	penger	MINKU	seter
KLØNESK	balanse	PRASSER	lakris	ISUK	sint
GLAFFER	banan	HIBBOLER	lue	LEGEK	sitron
RUMKEL	bokser	HYRG	parkett	GRUDDLE	garasje
GAFTOR	bokstav	FUNIG	maskin	SMERAS	slott
MIPER	bonde	KLIDDER	mat	MASLIG	smør
HÅSERK	brød	GLÆR	medisin	SNARGEL	snø
HEREK	spøkelse	GLØRES	melk	FLON	soldat
SELØR	dimensjon	HIDDLON	meter	FENIP	solskinn
FÅREM	dukke	LOGES	militær	MAGIRAT	søvn
UTBLU	dytte	DEGGES	minimal	STÆB	stab
SKIRMEL	eksempel	GELAR	motstand	LØRSE	pumpe
FROMTER	eple	HYROK	oppgave	NORMIGA	sykkel
LIMGER	erter	MYRNIG	panikk	MIRAK	terapi
ÅRSKAL	ess	EKLØD	paraply	FANOPI	termin
VUSHA	fartøy	ØRSKAR	politikk	PASKEL	trekkspill
FNIG	kniv	BLUROT	pølse	PROMER	troll
KLARINE	gevær	LASES	potet	LONKA	uhell
TORHOP	gitar	RUAK	hjelm	MASSELIB	vann
GYPN	grep	VERLIG	ros	SEIGTER	fiolin
AMSKER	hår	RUKLE	salt	HASKET	bunad
KOMPTOR	hatt	SMEIM	samtale		
URKALED	juks	IDYR	sand		
EKLOG	kalkun	KNIM	seilas		

8.3 English stimuli

Table 8-3 Real words

same	meal	MEAL	Last syllable	book	HOOK
same	scarf	SCARF	Last syllable	lion	ONION
same	goal	GOAL	Last syllable	hat	RAT
same	bakery	BAKERY	Last syllable	leg	EGG
same	friend	FRIEND	Last syllable	clock	STOCK
same	name	NAME	Last syllable	ball	HALL
same	voice	VOICE	Last syllable	candle	HANDLE
same	message	MESSAGE	Last syllable	stone	BONE
same	carpet	CARPET	Last syllable	snake	LAKE
same	beast	BEAST	Last syllable	goat	OAT
meaning	gloves	MITTENS	unrelated	robber	PUMPKIN
meaning	head	FACE	unrelated	airport	CHIMNEY
meaning	chicken	HEN	unrelated	bacon	SURFACE
meaning	fruit	BANANA	unrelated	colour	DUSTBIN
meaning	bread	DOUGH	unrelated	cheek	RADISH
meaning	desk	TABLE	unrelated	treasure	FENCE
meaning	cottage	LODGE	unrelated	coin	GHOST
meaning	salad	LETTUCE	unrelated	chocolate	SKIRT
meaning	lamb	SHEEP	unrelated	police	VAMPIRE
meaning	kitten	PUPPY	unrelated	berry	WINDOW
First syllable	grape	GRAVE			
First syllable	butter	BUTTON			
First syllable	hand	HAM			
First syllable	fox	FOG			
First syllable	tummy	TURTLE			
First syllable	bean	BEACH			
First syllable	money	MONKEY			
First syllable	cake	CAGE			
First syllable	roof	ROOSTER			
First syllable	cup	CUB			

Table 8-4 English pseudo-words with real word prime

Prime	TARGET	Prime	TARGET
tractor	TRACCAR	cover	CAOER
grease	SPEASE	cricket	GROCKET
saddle	SAMBE	death	DEALD
tennis	TENTUS	evening	ERSMING
whistle	STRISGE	flippers	BROPPERS
victim	CHICTIRD	flower	SPOSER
bull	BURES	fridge	FRIVED
damage	RAMAND	giant	WIASH
umbrella	UPSHULLA	harbour	HANVOUR
fork	FOSED	ladder	FADBER
admirer	ATLARER	machine	MASCIPS
angel	ANBYL	moose	MOOBS
assembly	ASSIRPHY	morning	MURTING
barrel	BARTUL	mustard	RUSTATE
bridge	BRIRKS	pencil	MENCYL
broom	BROAM	place	SWACE
camera	MIPERA	present	STOSENT
capital	CATILEL	referee	MAPEREE
ceiling	CAESING	scissors	DRISTORS
chalk	CHASK	shark	SAHZE
change	CHATHS	spice	SPIFT
chips	SPIPS	sweets	BREETS
cinema	CUNEPE	theatre	CLEAGLA
clouds	SLOUDS	toilet	LOFLET
comic	COXIF		
costume	COSTOCH		

8.4 L1 Statistics

Table 8-5 L1 correct answers organized by mean RT

Target word	Condition	Correct responses %	Mean RT	Target word	Condition	Correct responses %	Mean RT
PAPIR	same	85	580,81	KART	rhyme	90	652,94
RING	same	81	601,18	SOFA	unrelated	76	656,14
BENK	same	79	602,66	STANG	same	85	656,46
STOL	synonym	77	605,77	SKAP	synonym	85	657,05
NATT	alliteration	81	607,53	NESE	unrelated	85	657,25
STEIN	same	82	607,91	FLAGG	synonym	89	658,12
FEST	synonym	89	609,60	SKIP	alliteration	84	659,04
KULE	same	89	611,56	LAMPE	rhyme	85	661,39
FJELL	same	87	615,64	LAPP	alliteration	81	662,74
TELEFON	same	77	615,93	HEST	rhyme	82	665,91
BILDE	synonym	87	617,84	ESKE	same	65	667,60
GLASS	rhyme	94	617,86	NAVN	rhyme	87	667,69
SKOLE	unrelated	84	618,17	PARK	alliteration	81	668,52
HODE	rhyme	82	622,28	PISTOL	unrelated	84	669,36
VINDU	alliteration	79	622,92	KIKKERT	same	79	670,64
PIANO	same	81	623,85	SPOR	rhyme	65	673,00
SKYGGE	same	79	628,42	ULV	synonym	84	675,35
SEKK	rhyme	85	629,81	SANGER	unrelated	81	675,45
SOPP	unrelated	87	631,19	FLOKK	alliteration	73	679,33
SØLV	unrelated	98	632,12	FILM	alliteration	76	682,21
PAPPA	rhyme	84	633,05	KLASSE	rhyme	76	683,07
AGENT	same	77	633,29	GRUS	synonym	71	685,74
SPORT	unrelated	87	634,03	ANKEL	alliteration	68	688,36
DIAMANT	same	85	634,40	FINGER	synonym	82	688,68
AVIS	rhyme	89	638,94	LAGER	alliteration	73	689,71
PENN	alliteration	87	639,12	SLIM	unrelated	65	700,50
KURV	same	74	639,97	HULL	rhyme	82	702,11
PEIS	alliteration	79	640,09	SVETTE	unrelated	74	703,58
SPILL	unrelated	89	641,19	KONTROLL	synonym	85	708,91
GULV	synonym	85	642,10	BRILLER	synonym	74	714,01
LEGE	alliteration	87	642,10	SKØYTER	unrelated	82	719,94
KANT	rhyme	76	642,37	MALING	unrelated	73	723,92
PYTT	rhyme	69	645,29	DROSJE	synonym	73	726,20
GUTT	rhyme	85	645,31	FLASKE	synonym	71	726,67
BEIN	synonym	89	646,72	KLYPE	alliteration	68	730,59
DATO	alliteration	84	646,97	HØVDING	unrelated	53	752,40
DIKT	synonym	87	650,96	VITNE	unrelated	65	754,93
HAGE	alliteration	82	652,52				

Table 8-6 L1 correct responses organized by %

Target word	Condition	Correct responses	Correct responses in %	Target word	Condition	Correct responses	Correct responses in %
HØVDING	unrelated	33	53	HEST	rhyme	51	82
ESKE	same	40	65	FINGER	synonym	51	82
SPOR	rhyme	40	65	HULL	rhyme	51	82
SLIM	unrelated	40	65	SKØYTER	unrelated	51	82
VITNE	unrelated	40	65	SKOLE	unrelated	52	84
ANKEL	alliteration	42	68	PAPPA	rhyme	52	84
KLYPE	alliteration	42	68	DATO	alliteration	52	84
PYTT	rhyme	43	69	SKIP	alliteration	52	84
GRUS	synonym	44	71	PISTOL	unrelated	52	84
FLASKE	synonym	44	71	ULV	synonym	52	84
FLOKK	alliteration	45	73	PAPIR	same	53	85
LAGER	alliteration	45	73	SEKK	rhyme	53	85
MALING	unrelated	45	73	DIAMANT	same	53	85
DROSJE	synonym	45	73	GULV	synonym	53	85
KURV	same	46	74	GUTT	rhyme	53	85
SVETTE	unrelated	46	74	STANG	same	53	85
BRILLER	synonym	46	74	SKAP	synonym	53	85
KANT	rhyme	47	76	NESE	unrelated	53	85
SOFA	unrelated	47	76	LAMPE	rhyme	53	85
FILM	alliteration	47	76	KONTROLL	synonym	53	85
KLASSE	rhyme	47	76	FJELL	same	54	87
STOL	synonym	48	77	BILDE	synonym	54	87
TELEFON	same	48	77	SOPP	unrelated	54	87
AGENT	same	48	77	SPORT	unrelated	54	87
BENK	same	49	79	PENN	alliteration	54	87
VINDU	alliteration	49	79	LEGE	alliteration	54	87
SKYGGE	same	49	79	DIKT	synonym	54	87
PEIS	alliteration	49	79	NAVN	rhyme	54	87
KIKKERT	same	49	79	FEST	synonym	55	89
RING	same	50	81	KULE	same	55	89
NATT	alliteration	50	81	AVIS	rhyme	55	89
PIANO	same	50	81	SPILL	unrelated	55	89
LAPP	alliteration	50	81	BEIN	synonym	55	89
PARK	alliteration	50	81	FLAGG	synonym	55	89
SANGER	unrelated	50	81	KART	rhyme	56	90
STEIN	same	51	82	GLASS	rhyme	58	94
HODE	rhyme	51	82	SØLV	unrelated	61	98
HAGE	alliteration	51	82				

8.5 L2 statistics

Table 8-7: L2 correct answers organized by mean RT

Target word	condition	%	Mean RT	Target word	condition	%	Mean RT
VOICE	same	79	575,7352	FOG	alliteration	62	662,3608
NAME	same	86	579,6411	CUB	alliteration	50	665,1895
MONKEY	alliteration	93	596,6577	BONE	rhyme	64	666,0952
GOAL	same	81	598,0918	HANDLE	rhyme	76	666,4488
RADISH	unrelated	24	604,1420	BAKERY	same	76	673,9356
FRIEND	same	88	604,7141	WINDOW	unrelated	79	678,6858
MEAL	same	81	608,4618	MITTENS	meaning	33	678,7750
HALL	rhyme	71	613,9817	HOOK	rhyme	52	679,1455
EGG	rhyme	90	620,6650	ONION	rhyme	57	679,5862
BANANA	meaning	88	626,1476	GHOST	unrelated	88	680,3197
CARPET	same	62	638,5454	TABLE	meaning	79	681,8624
PUPPY	meaning	76	642,2041	BUTTON	alliteration	88	693,0976
GRAVE	alliteration	71	642,9347	SKIRT	unrelated	60	698,1736
SCARF	same	69	645,2676	BEAST	same	67	700,1575
FACE	meaning	88	645,4892	VAMPIRE	unrelated	74	702,4945
RAT	rhyme	81	648,8112	TURTLE	alliteration	74	706,2410
BEACH	alliteration	74	648,9019	FENCE	unrelated	50	706,4090
LAKE	rhyme	74	649,6277	CAGE	alliteration	31	712,3000
DUSTBIN	unrelated	24	652,4160	STOCK	rhyme	60	719,1644
HAM	alliteration	62	655,7392	SURFACE	unrelated	45	720,4237
LETTUCE	meaning	12	656,5720	LODGE	meaning	24	724,8630
SHEEP	meaning	69	658,3131	PUMPKIN	unrelated	83	740,9834
OAT	rhyme	29	658,6142	DOUGH	meaning	40	743,2606
MESSAGE	same	81	658,9324	CHIMNEY	unrelated	26	795,4855
HEN	meaning	71	660,2283	ROOSTER	alliteration	36	803,6893

Table 8-8 Correct responses organized by percentage

Target word	Condition	Correct responses	Correct responses %	Target word	condition	Correct responses	Correct responses %
LETTUCE	meaning	5	12	GRAVE	alliteration	30	71
RADISH	unrelated	10	24	HEN	meaning	30	71
DUSTBIN	unrelated	10	24	BEACH	alliteration	31	74
LODGE	meaning	10	24	LAKE	rhyme	31	74
CHIMNEY	unrelated	11	26	VAMPIRE	unrelated	31	74
OAT	rhyme	12	29	TURTLE	alliteration	31	74
CAGE	alliteration	13	31	PUPPY	meaning	32	76
MITTENS	meaning	14	33	HANDLE	rhyme	32	76
ROOSTER	alliteration	15	36	BAKERY	same	32	76
DOUGH	meaning	17	40	VOICE	same	33	79
SURFACE	unrelated	19	45	WINDOW	unrelated	33	79
CUB	alliteration	21	50	TABLE	meaning	33	79
FENCE	unrelated	21	50	GOAL	same	34	81
HOOK	rhyme	22	52	MEAL	same	34	81
ONION	rhyme	24	57	RAT	rhyme	34	81
SKIRT	unrelated	25	60	MESSAGE	same	34	81
STOCK	rhyme	25	60	PUMPKIN	unrelated	35	83
CARPET	same	26	62	NAME	same	36	86
HAM	alliteration	26	62	FRIEND	same	37	88
FOG	alliteration	26	62	BANANA	meaning	37	88
BONE	rhyme	27	64	FACE	meaning	37	88
BEAST	same	28	67	GHOST	unrelated	37	88
SCARF	same	29	69	BUTTON	alliteration	37	88
SHEEP	meaning	29	69	EGG	rhyme	38	90
HALL	rhyme	30	71	MONKEY	alliteration	39	93