A study of cross-linguistic form and meaning priming through reaction times in lexical decision tasks

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Abstract

In a series of open priming lexical decision tasks, the influences of meaning form and lexical reaction time were investigated. All experiments used the same stimuli in order to be able to compare the collected reaction time data across all experiments. The form and meaning influences on cross-linguistic English and Norwegian stimuli were tested across four categories: cognates (+ meaning, + form), translations (+ meaning, - form), lookalikes (- meaning, + form) and unrelated (- meaning, - form). Experiment 1 was a one-directional lexical decision task, where all primes were English words and their respective targets were Norwegian or non-words (L2-L1). Experiment 2 investigated the same stimuli in the opposite language direction, such that all primes were Norwegian and their respective targets were English or non-words (L1-L2). Experiments 3 was a direct replica of experiment 2, although recruiting a different set of participants where the participants were beginner-learner Norwegian speakers with a first language that differs from English (L3-L2). Experiment 4 was a mixed language experiment, where half of the targets in each category was English primed by Norwegian and the other half were Norwegian primed by English (L1-L2 and L2-L1). The four experiments show a main effect form meaning (47ms), however form effects did not reach significant levels in experiments 1-4.

A separate (unprimed) baseline study was conducted to account for any potential problems with the stimuli. This made it possible to correct the first four experiments against the lexical reaction times collected in the baseline study. A correction for lexical reaction times indicated that the highly significant main effect for meaning in the first four experiments, although smaller, continued to facilitate response times (25ms). The form effects were non-significant after correction. However, a between subject baseline may not be ideal, as the differences in proficiency and subjective frequencies cannot be accounted for sufficiently.

Experiments 5-8 are slight variations of the mixed language experiment (4), with a counterbalanced within subject baseline. These experiments were analyzed together in order to account for priming effect for each word pair in both language direction (English-Norwegian and Norwegian-English). The counterbalanced baseline accounted for the lexical reaction times, such that when the mean lexical reaction time was accounted for, the priming effects are clearer. A significant main effect for meaning was found (-32.4ms). In line with the observations from experiments 1-4, form effects were non-significant.

The accumulated results from all experiments suggest that, at least when the prime is visible for 100ms, the meaning bearing units for the prime words are activated aiding the process of word recognition in any of the language directions across these series of experiments. The form similarities did not reach significance, indicating that the across-language form similarities are non-significant aids when the meaning is activated.

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Chapter 1

Introduction

This section will outline an introduction to the research topic, define key terms, explain research objectives, and at the end the organization of the text will be described.

1.1 Introduction to the research topic

In today's globalized world, people interact over boarders and between different cultures. A natural outcome of this is that more and more people are becoming bilingual or even multilingual. Probably more than half of the world's population has at least some limited knowledge of a second language (see Grosjean and Li (2012) for a more detailed discussion), so it is not surprising that the interest in the study of the language systems of bilingual speakers increases exponentially.

The beginning of extensive research of the mental representation and processing of bi- and multilingual speakers, can be traced back to the 1960's (Szubko-Sitarek, 2015; De Groot, 1993).Early theories of language models are based on observation and self-observation of the linguistic behavior of bilinguals. The question of how a bilingual's mental lexicon is represented became an important part of the psycholinguistic research during the years following the publication of (Weinreich, 1953). Three proposed structures of how a bilinguals two languages could possibly interconnect and/or coexist in a bilinguals mind became the center of attention in psycholinguistic research during the following decades and a number of theories with their basis on the *coordinative, subordinative and compound* hypothesis' emerged.

Some of the most enduring questions in psycholinguistic research concern the structure of and processes governing the mental lexicon. Central questions concerning the structure of languages center around how words are stored in the mental lexicon. How a single language connects with its different prats, i.e. is the English word *cat* stored near the phonetically similar *catch*, to the orthographically similar *cot* or is it connected to the semantically similar word *dog* (Warren, 2012), and how these connections are across languages.

The investigation of semantically related words such as *cat* and *dog* became an interesting source of stimuli in cross-linguistic experiments. A common research question regarded the difference between semantically related pairs across languages and translation pairs. Chen and Ng (1989) found in a cross-script experiments with Chinese-English participants that facilitation effects were grater when the target was primed with a translate rather than a semantically related word. A cross-language study by Schoonbaert et al. (2009) found that both significant results for translation priming and semantic priming in lexical decision tasks between English and Dutch, suggesting that both L1 and L2 are represented by a similar lexico-semantic architecture.

Through a number of cross-linguistic semantic and translation studies, a commonly acknowledged facilitatory effect for translation primes has been established. The semantic facilitation, although present has consistently been reported as weaker than the translation effect (Schoonbaert et al., 2009). Current research centers around the question of how the semantic influences reaction times in cognates and interlingual homographs (Lemhöfer and Dijkstra, 2004). This study will further investigate how the meaning and form similarities across languages influence the response time in a series of open priming lexical decision tasks. This will be achieved through comparing cross-languages word pairs of cognates (+ meaning and + form), translations (+ meaning - form) and lookalikes (- meaning and + form) with a baseline (- meaning and - form).

1.2 Definition of key terms

Before digging deeper into the minds of bilinguals or multilinguals, it is best to explain what is meant by these descriptions, as there is no clear consensus on how bi- and multilingual speakers are defined. Bilinguals are often referred to as speakers of one or more languages, although this definition is in clear contrast to the meaning of the prefix ”bi-”, which means two (Grosjean and Li, 2012). By definition, a bilingual speaker should then, only be a speaker of two languages. The definition of multi- does not, however exclude the speaker from speaking only two languages. The definitions based on the concrete meanings of the prefixes ”bi-” and ”multi-” are not always followed, as argue that the term bilingual can refer to persons who speak, need and use two or more languages (Grosjean and Li, 2012). In this study the latter definition will be applied. The present study focuses on aspects of how *two* languages interact, although most, if not all participants are multi- rather than bilinguals.

There is also a definition dispute regarding the languages of bi- and multilingual speakers. Researchers have referred to a second language as L2, third language as L3 and so on. To make it more complex L3 has often not only been used to define the third acquired language, but also to define the set of languages in the ”third language group”. Moreover these definitions do not consider language proficiency, which is perhaps an equal important factor as the order of acquisition. Within this study a number of cross-linguistic experiments recruited participants classified as Norwegian (L1) speakers. Although the case may be that for some of the participants Norwegian was not in fact their first language, however where Norwegian is referred to as L1, it was always the case that participants judged this to be their dominant language. English is referred to as L2 within the experiments, although it may very well be the case that participants learned English as their third language. The language proficiency of the English (L2) speakers is judged to be at a proficiency level where participants do not have problems reading an English newspaper. One experiment within this study recruited English (L2) speakers, whit different dominant languages. Norwegian is in this case referred to as L3, however this does not indicate that participants of this study do not know any other languages than their L1 and L2 language.

1.3 Research hypothesis

Orthographic similarities across languages such as are found in interlingual homographs (false friends or lookalikes) and cognates have been central in recent cross-linguistic research (Lemhöfer and Dijkstra, 2004). A number of studies indicate that word candidates across languages are co-activated in the initial process of (written) words recognition (Lemhöfer and Dijkstra, 2004; Dijkstra and Van Heuven, 2002). According to the BIA+ model the orthographic input activates associated semantic and phonological representations across languages, creating an interaction where the lexical candidate corresponding to the input emerges and is recognized (Lemhöfer and Dijkstra, 2004, p.533). The BIA+ model proposes that interlingual homographs have separate representations for each language, whereas it is undetermined if the same is the case for cognates (Lemhöfer and Dijkstra, 2004, p.533).

This study aims to further investigate the form and meaning aspects of (nonidentical) interlingual homographs and (nonidentical) cognates and compare these to translations which share no orthographic overlap. This was achieved through a series of lexical decision task in an open priming paradigm, where variations of the same cross-linguistic priming experiment investigate reaction time differences between the conditions of +/-meaning and +/- form. The main interest of this study is to investigate how meaning and form similarities and differences influence reaction time in cross-linguistic priming studies and how much of the found effects can be attributed to priming.

1.4 Organization of the text

Chapter 2 will discuss theories of language organization, form the first proposed models of language organization to the more recent models of language processing. An outline of the research methods and the experimental stimuli used for the experiments will be outline in chapter 3. The individual experiments and their results will be discussed in chapter 4 and 5 will give an overview of our findings and their implications on current theories will be discussed.

Chapter 2

Theory

Weinreich (1953) proposes, in Sausserian linguistic terminology, three theories of how the languages of a bilingual are effecting the *sign* (which combines a unit of content *signified* and expression *signifier*): *coordinate, compound and subordinative bilingualism*. These theories, as shown in section 2.1.1, differ in two main aspects: the number of conceptual stores and how the bilingual's two languages access these.

The division of conceptual knowledge and a bilinguals lexica form the basis of the first models of a bilingal's language structrue. The proposed possible organizations of a bilingual's languages as and how bilinguals access conceptual representations Weinreich (1953) proposed, emerged with marginal changes under a number of different labels and were often seen as competing models during the decades that followed (De Groot, 1993).

In section 2.1 theories proposed by Weinreich (1953) will be introduced in more detail, as well as a few of the theories following her original assumptions about bilingual language organization and conceptual access. These theories include *word association model* and the *concept-mediation model*. The focus of these early models was on the common versus shared storage hypothesis debating if the languages of a bilingual are stored in a common or a separate language system. As research indicated an asymmetry in language knowledge these *revised hierarchical model* became popular. The new model bases its assumption on asymmetrical language knowledge and combines parts of the word association and the concept-mediation models into a model that takes language proficiency into account (Jiang, 1999; Keatley et al., 1994; Basnight-Brown and Altarriba, 2007).

Although the debate about a shared versus a separate language store has continued to interest researchers in the field of psycholinguistics, the early models propose a challenge to answering this question. The generality of the models failed to consider levels of representation procedural differences and the processes that are involved in understanding and uttering language. Section 2.2 will outline the more recent theories of language processing such as the *Bilingual Interactive Activation Model* which was built on the assumptions made in its monolingual predecessor *Interactive Activation Model*.

2.1 Concepts and Lexica

The main focus of the early models of language organization concern the debate of whether a bilinguals languages are directly connected to each other, if they are connected to a common conceptual store or if they are completely separate form each other. The differences are found in three main theories: Coordinative, Compound and Subordinative. Followed by the reinterpretation of these in the Word-association model and concept mediation models and the Revised hierarchical model.

2.1.1 Coordinative, Compound and Subordinative Bilingualism

The coordinative, compound and subordinative bilingualism hypothesis, first proposed by Weinreich (1953), are the first models of the structure of bilingual language processing. These early theories mark the start of a rapidly growing interest in bilingual language processing and production within the field of psycholinguistics.

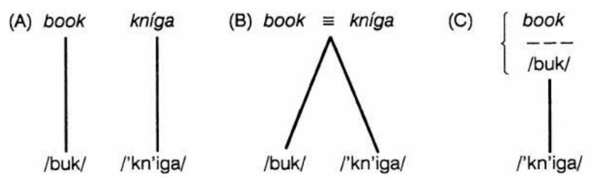

Figure 2.1: Coordinate (A), Compound (B) and Subordinative (C), originally printed in Weinreich (1953)

The coordinative bilingualism hypothesis proposes that each *signifier* correlates to one *signified*, meaning that there is one conceptual representation for each of the words in the first language and a separate conceptual representation for each of the words in the second language. A bilingual's language systems are thus, according to the coordinative bilingualism hypothesis, completely separate; neither sharing a lexicon nor the conceptual representations as can be seen in figure 2.1 (A) (Weinreich, 1953; De Groot, 1993).

Figure 2.1 (A) shows the surface forms of the word *book* in English /buk/ and in Russian /'kníga/. These surface forms are attached to the conceptual representations 'book' and 'kníga' respectively. As can be seen, there is no interaction between the English and Russian representations on a conceptual or lexical level.

The compound bilingualism hypothesis on the other hand, proposes that there is one *signifier* which correlates to two *signified*, such that a word in the first language and its translation equivalent in the second language share a common conceptual representation. The compound bilingualism hypothesis as represented in figure 2.1 (B) shows the conceptual and lexical representations of the word *book* again.

In the compound bilingualism hypothesis *Book* is represented by the surface forms in

English /buk/ and Russian /’kníga/, these are connected to a shared conceptual store, which contains both the conceptual representation for the English ‘book’ and the Russian ‘kníga’. Either surface form can be retrieved from the collective conceptual representation.

The coordinative (A) and compound bilingualism (B) hypothesis differ thus only in one respect: whether a bilingual’s languages share one conceptual store where both languages have access, or if each of a bilingual’s languages has access to a language-specific conceptual store.

The subordinative bilingualism hypothesis proposes, in accordance with the compound hypothesis, that there is only one conceptual store. The manner in which this conceptual store is accessed distinguishes these hypotheses. The subordinative bilingualism hypotheses assumes that the *signifier* only correlate to the *signified* of the first language, and the second language *signified* connects to the translation equivalent in the first language, before accessing the conceptual store.

Figure 2.1 (C) shows the second language (Russian) surface form /’kníga/ connects directly to its translation equivalent, the English surface form /buk/, and only through the translation process can the concept of ‘book’ be accessed. The first and second languages are thus only connected at a word-to-word level, where the second language word is dependent on the first language word in order to access the conceptual representation.

Although these three theories are often seen as competing theories in the literature during the following decades, Weinreich (1953) argued that *‘... a person’s or group’s bilingualism need not be entirely* coordinative *or* compound*, since some signs of the language may be compounded while others are not‘* (Weinreich, 1953, p.10). Assuming then that a person’s learning histories and proficiency levels affect the structure of a bilingual’s language representation. Weinreich (1953) further assumed that there should occur a shift from subordinative to coordinative and/or compound bilingualism as a language learner grows more fluent in their second language. Arguing for a bilingual’s language representation where the coordinate, compound and subordinative bilingualism hypotheses may coexist, even within a single individual and that connections may shift as connections grow stronger.

The most commonly adopted view was that there might either be a shared conceptual store that both languages have access to, or a separate language-specific conceptual store. This distinctions of the number of conceptual stores emerged under a number of different labels and will be discussed in section 2.1.2. A second distinction that has been given a lot of attention in the literature was whether a bilingual accesses the conceptual store through the process of translation from a second language to the first or whether both languages have access to the conceptual store. This distinction will be discussed further in section 2.1.3.

2.1.2 Compound vs Coordinate Bilingualism

Theories centering around the distinction between one or two conceptual stores, such as the compound and coordinative bilingualism hypothesis, are often assumed to be in direct competition. The distinction of conceptual stores emerged in the literature under labels such as *common* or *shared storage* versus *separate storage* hypothesis (Kolers, 1963; Kolers and Gonzalez, 1980) and the *interdependence* versus the *independence* hypothesis (Jin, 1990; McCormack, 1977). These theories are modified versions of the original hypothesis Weinreich (1953), with clarifications to the way in which a language accesses and stores languages and concepts.

According to the shared storage hypothesis a bilinguals past experiences are tagged and coded into a common supralinguistic conceptual store, where some concept or event could be retrieved in any of the bilinguals languages, independent of which language it was originally coded in. Whereas the separate storage hypothesis proposes that the tagged and coded forms are stored in language specific conceptual stores, such that a bilingual would require an additional event of translation in order to retrieve an event in one language, which was stored in another (De Groot, 1993).

De Groot (1993) argues that different learning environments could account for different systems of conceptual representations. A common storage system could be a result of strategic learning processes implemented in school, where the first and second language share a the knowledge of concepts through first language mediation (first through a translation process and as the links grow stronger through immediate access to the conceptual store, bypassing the translation) (De Groot, 1993, p. 30). A common system for conceptual stores could also be a result of a bilingual's interchangeable use of both languages in all situations. However, if a bilingual consistently uses one language in a distinct separate national and cultural setting it may result in a separate conceptual store for each of the languages (De Groot, 1993).

Studies have found both evidence supporting a common storage hypothesis (McCormack, 1977) and a separate storage hypothesis (Kolers, 1963). Durgunoglu and Roediger (1987) argue that neither the coordinative nor the compound hypothesis can be dismissed *the issue of whether bilinguals store information in one or two codes seems indeterminable, because the varying retrieval demands of different tasks produce different patterns of results and lead to opposite conclusions* (Durgunoglu and Roediger, 1987, p.377). Tasks which are primarily conceptual driven (free-recall) tasks, produced results indicating a common conceptual store whereas task which are data driven (fragment-completion) produced results indicating a separate conceptual storage system (Durgunoglu and Roediger, 1987).

2.1.3 Word Association vs Concept Mediation

Subordinative and compound bilingualism emerged as competing models under the labels *word-association model* and the *concept mediation model* respectively (Potter et al., 1984; Kroll et al., 1988; Chen and Leung, 1989; Kroll and Stewart, 1994). The word association model proposes in accordance with the subordinative bilingualism hypothesis a word-to-word connection between the first and second language, where access to the conceptual store is only gained through first language mediation. The concept mediation model proposes a shared conceptual system for all languages, where words of the first and second language are independent of each other, but connected to a common amodal conceptual representation to which pictured objects also have access (Potter et al., 1984).

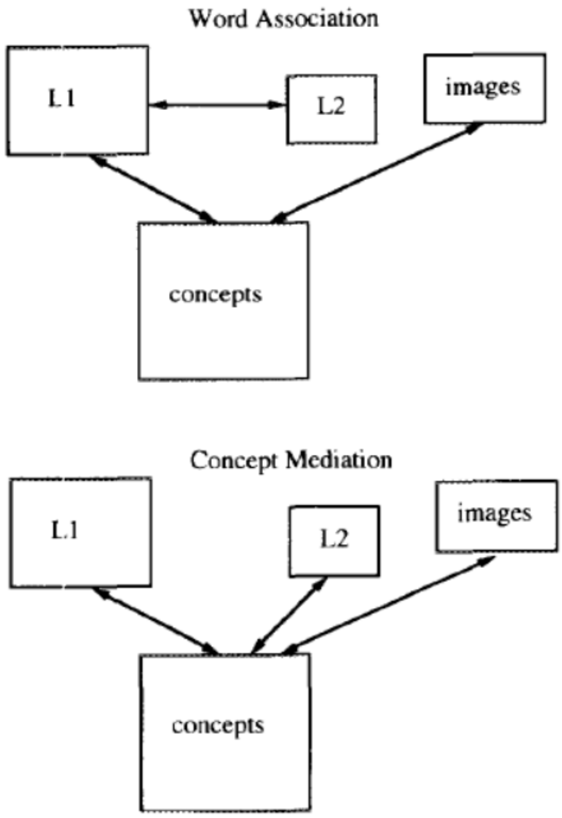

Figure 2.2: Word association and concept mediation models of language representation (Kroll and Stewart, 1994, p.150)

The word-association model and the concept mediation model provide two different assumptions about the links between two languages and their conceptual representations. Support for either theory is derived from two type of reaction time experiments, picture naming (in the second language) and translation (from the first language to the second) tasks (De Groot, 1993; Kroll and Stewart, 1994). The concept mediation model predicts equal reaction times for both translation tasks and for picture naming tasks, as the processing steps leading to the second language output only differ for the first two steps: concept retrieval is in one case reliant on the image input and in the other case, on word recognition. The word-association model predicts shorter reaction times or translations tasks than for picture naming tasks, as the translation process relies on lexical links between the first and second language, and can thus bypass conceptual access for translation tasks. The picture naming task requires conceptual access and mediation through the first language, before following the lexical links between the first and second language in order to produce the second language output, and should thus require more processing time.

Potter et al. (1984) tested both Chinese-English bilinguals who had learned English as a second language in a school setting and had lived and studied in an English speaking country for more than one year, and a less-fluent group of English-French bilinguals who had learned French in a school setting for 2-3 years. Both Chinese-English bilinguals and the less fluent English-French bilinguals performed in accordance with the concept mediation model.

Kroll et al. (1988) replicated the Potter et al. (1984) study, proposing that the less fluent group (English-French bilinguals) had already passed the critical period of second language learning, where the lexical links established for the first language mediate the second language word processing. The group of second language learners which had studied the second language for less than two years produced results in accordance with the word-association model, translating words was faster than naming pictures. Evidence of this shift in language processing lead to the proposal of a developmental hypothesis, in accordance with that first proposed by Weinreich (1953).

Proficient bilinguals performed in accordance with the concept-mediation model, whereas early language learners provided evidence for the word-association model (Potter et al., 1984; Kroll et al., 1988; Kroll and Stewart, 1994). The distinction between the conceptual and lexical level have been central to theories regarding multiple language processing and organization, and is based on observations of asymmetry between pictures and words. This asymmetry was found in naming tasks, where words were consistently named 200-300 ms faster than pictures of the same items (Kroll and Stewart, 1994; Cattell, 1886). In tasks where pictures and words were to be matched to superordinate conceptual category on the other hand, responses for picture naming were just as fast or faster as responses for words. The asymmetry which was found indicates a functional division, where tasks requiring conceptual access and lexical access are consistently performing differently (Potter et al., 1984).

2.1.4 The Revised Hierarchical Theory

The Revised hierarchical model assumes that both the lexical links and the conceptual links are active in a bilinguals memory, where the word-to-word links and the word-to-concept links are bidirectional (Kroll and Stewart, 1994). The strength of these links are dependent on the proficiency level of the speaker, and are assumed to be asymmetrical, where the most proficient language possesses the strongest links between its lexicon and the conceptual store. The links of a language learner are assumed to be connected at a word-to-word level in the early stages and supplemented with conceptual connections as the language learner grows more proficient, though both lexical conceptual connections are present in a fluent multilingual. To accommodate this asymmetry between translation from a first to a second language and vice versa, (Kroll et al., 1988; Kroll and Stewart, 1994) propose a version of a hierarchical model.

The hierarchical model predicts that the dominant language is the first language, where the translation process from the first language to the second should be sensitive to conceptual information. The same should not hold for the translation process from the second to

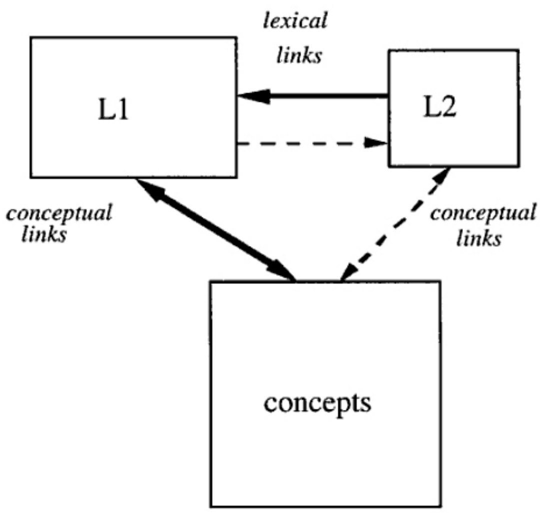

Figure 2.3: The revised hierarchical theory Kroll and Stewart (1994)

the first language, as the conceptual links are not necessarily involved in second to first language translations. In order to test this hypothesis Kroll and Stewart (1994) conducted translation experiments for Dutch-English bilinguals, with either randomized or categorized word lists, predicting category interference only for fluent bilinguals in the first to second language translation process. A pre-test recall task was carried out, to test the hypothesis that recall following a translation process from the first to the second language should be better, as it involves concept mediation. Kroll and Stewart (1994) found no interference on list effects, categorized or randomized, for second to first language translation. The first language to second language translation, as hypothesized to be conceptually mediated, showed category interference. For the recall-tasks, the predicted context mediation from first to second language translation produced a category advantage, whereas the translation process from second to first was insensitive to category effects. Both the interference within the translation task and the advantage within the recall tasks indicate that there are differences between the first and second language and their conceptual and lexical access, as predicted by the revised hierarchical model. Basnight-Brown and Altarriba (2007) argue that, although the revised hierarchical model does account for the asymmetry found between first and second languages, this model does not account for the possibility of language-specific concepts, where the translation equivalent does not exist.

2.2 Interactive Models

The early models described so have failed in addressing issues such as distinctions amongst levels of representation processing tasks and language development. A shift form the general storage based systems towards interactive models of language processing occurred. Where the first models were general models of semantic and lexcial access, the following models aim to describe the processes which govern the selection of lexical and semantic information, as well as providing a more detailed way of how two languages may interact.

2.2.1 WEAVER++

Lexical access is a core component of word production, and a normal speaker is able to produce at average two and up to five words per second, which suggests that speakers can access lexical content at this rate (Roelofs, 1992). The process of word production is based on a two-system architecture and it is important to consider the process of word production as it is intertwined with important constructs of the mental lexicon, see section 2.2.5 (Levelt, 2001). The WEAVER (Word-form Encoding by Activation and VERifiction) model is the computational implementation of the model of speech production proposed by Levelt (2001) and covers the process of word production from the initial focusing of a concept to the syllabification of operations which precede the articulation of that concept (Roelofs, 1992, 1997).

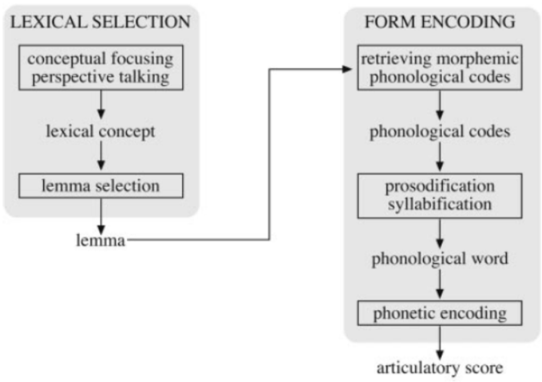

Figure 2.4: Serial Two system architecture (Levelt, 2001, p. 13465)

Levelt (2001) argues for a speech production system of a serial two-system architecture as can be seen in 2.4, with two stages of lexical selection followed by three stages of form encoding. The first step in the word production system is in the retrieval of the lexical concept, with a particular communicative goal in mind. In terms of speech production in an experimental setting, a participant has to consider the amount of information the experimenter expects, what the sufficient amount of information is and/or how specific to be[1]. Picture naming is a common experimental paradigm in testing word production and interference. Levelt (2001) argues that in the case of picture naming where the participant has to decide if the picture of for example a horse should be named as *horse*, *stallion* or *animal* the first stage of the production of a an answer is a *perspective taking* stage. In this stage the speaker considers the listener, in order to make the speech act a communicative action, considerably following Grice's maxims (Wilson and Sperber, 1981).

[1]Ignoring the well known case of overspesification found in experimental studies

Perspective taking was considered part of the first stage of word production. The Levelt (2001) two forms of perspective taking in a directional description of a spatial pattern, *intrinsic* and *relative*. Formal properties of the intrinsic and relative perspectives are fundamentally different and are, as the choice of specificity, part of the fist stage of the serial two-system model of speech production. When faced with a directional description of a spatial pattern, where participants either responded in a matter consistent with *intrinsic* (directional 'mental body tour') or *relative* (subjective 'gaze following') perspective.

The concept in focus during the perspective taking stage is co-active with related lexical concepts, which are represented in the mental lexicon. The active lexical concepts spread activation to corresponding lexical items, which Levelt (2001) calls lemmas. The lemmas are essentially syntactic descriptions of the mental concepts and are coded for syntactic properties such as, *singular/plural*, *number* and *gender*. The selection of the lemma is a spreading activation process, where the WEAVER++ model predicts semantic inhibition from related concepts as can be seen in figure 2.4. If the target word is *animal*, where both *horse* and *goat* are in the subset of, the semantic similarity produces a facilitatory effect. If however the target word is *horse*, where *horse* is in direct competition with the semantically related *goat*, inhibitory effect occur (Levelt, 2001; Roelofs, 1992)[2].

Once a lemma is selected its syntactic properties, grammatical encoding and the grammatical context in which the lemma is to appear are further subject to processing. The syntactic features connected to the lemma, are not as any other feature assumed to be a result of selection under competition, Levelt (2001) argues however that the access of the syntax of items is a field which has not been explored sufficiently. The lemma, with its syntactical properties, is then subjected to the next step of the word production process; form encoding.

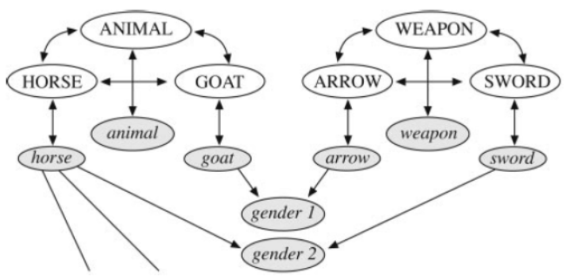

Figure 2.5: Lexicla selection (Levelt, 2001, p. 13465)

After the appropriate lemma is selected, the encoding process begin. Levelt (2001) argues that the activated lemma alone spreads activation to the phonological codes of the lemma. In the case of a multimorphemic lemma, the phonological coding is received for each of the morphemes. The phonological coding comprises of ordered sets of phonological segments

[2]The selection is not consistently conceptually driven. In cases such as the selection of prepositions (e.g. that), the lemma selection is dependent on syntactic operations, rather than conceptual activation, further discussing of this aspect is outside the scope if this paper(Levelt, 2001).

which form the input of the prosodification or syllabification level of the form encoding process. Syllables are context dependent and are subject to change in the case of, for example a syntactic shift from singular to plural. It follows then that an items syllabification is not stored in the mental lexicon, but created with regards to the current context. The incrementally composed syllables are in turn input to the final steps of the encoding process phonetic encoding and articulation.

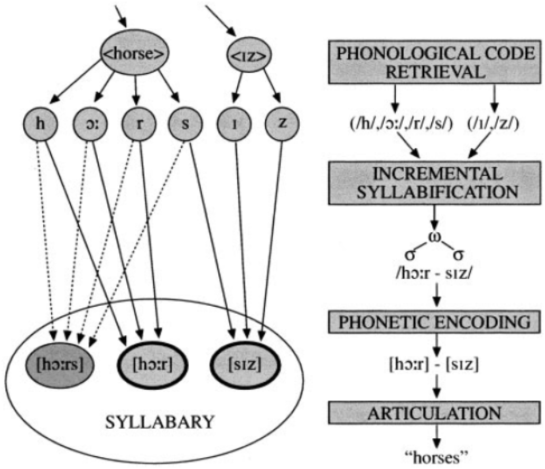

Figure 2.6: Form Encoding network (left) with corresponding form-processing stages (right). (Upper stratum) Nodes representing morphemic phonological codes and their phonemic "spellouts". (Lower stratum) Nodes representing syllabic articulatory scores (Levelt, 2001, p. 13465).

2.2.2 Interactive Activation Model

Where the WEAVER++ model focuses on the word production, the interactive activation model focuses on the visual word processing. The perceptual advantages of word, also called the word superiority effect, which was first identified during the late 1800s (Cattell, 1886), show an advantage of letter identification in familiar context (a known word) over identification within a letter string which is not familiar. This word superiority was found in experiments using whole reports of letters presented, which was later argued to be subject to guessing biases and postperceptual processing (McClelland and Rumelhart, 1981). In order to test this word superiority Reicher (1969) conducted additional experiments comparing words, unpronounceable non-words and single letters in a forced-choice task, with two single letter targets. The forced-choice task produced more accurate results for letter choice in the word condition than for the non-word or single letter condition, thus reinforcing the findings of the word superiority effect (Cattell, 1886). This effect has been found irrelevant of word shape, the same word superiority effect was found in lower case, upper case and in a mixture of lower and upper case letters within a number of experiments (Reicher, 1969; McClelland

and Rumelhart, 1981). An advantage of pseudo-words (pronounceable non-words) over unpronounceable non-words and single letters as well as a dependence on the visual mask was found in a number of studies (Aderman and Smith, 1971; Baron and Thurston, 1973; Spoehr and Smith, 1975; McClelland and Rumelhart, 1981).

The Interactive activation model, as proposed by McClelland and Rumelhart (1981); Rumelhart and McClelland (1982), takes the effect of word superiority and the interaction of a word's visual features as contextual clues into considerations. *The basic idea is that the presentation of a string of letters begins the process of activating detectors for letters that are consistent with the visual input. As these activations grow stronger, they begin to activate detectors for words that are consistent with the letters, if there are any. The activated detectors then produce feedback, which reinforces the activation of the detectors of the letters in the word. Letters in words are more perceptible, because they receive more activation than representations of either single letters or letters in an unrelated context* (McClelland and Rumelhart, 1981, p.376). The interactive activation model assumes that there is a system which consists of several levels of processing, where each level is concerned with forming a representation of the perceptual input at different level of abstraction. At each of these levels of abstraction there are nodes, representing every possible element within that level.

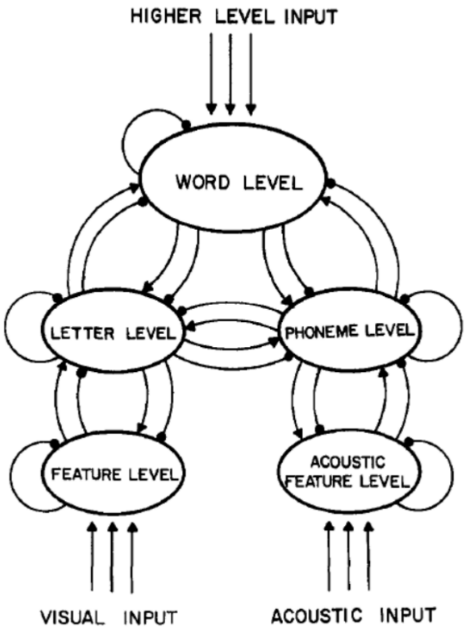

Figure 2.7: Interactive activation model*bottom-up* visual and acoustic input and *top-down* higher level semantic input (McClelland and Rumelhart, 1981, p. 378)

The processes involved in visual word processing are assumed to be active simultaneously at different levels for more than one visual feature at a time and involve a *bottom-up* as well as a *top-down* interaction. The data driven *bottom-up* processes, which are determined by the visual input, are interacting with the conceptually driven *top-down* processes and are conjointly determining what we perceive. These processes are interacting through simple excitatory and inhibitory processes (McClelland and Rumelhart, 1981).

The interaction between levels is assumed to occur through a spreading activation process which is governed by these excitatory and inhibitory processes. The excitatory connections increase the level of activation of their recipients,in figure 2.7 these are represented by arrows and the inhibitory connections decrease the activation of their recipients and are represented by connections with circular ends. Both connections can be active within or across adjacent levels, while connections between non-adjacent levels do not occur. Circular connections within one level are inhibitory connections where representations mutually inhibit each other, as they compete as possible interpretations of the visual input.

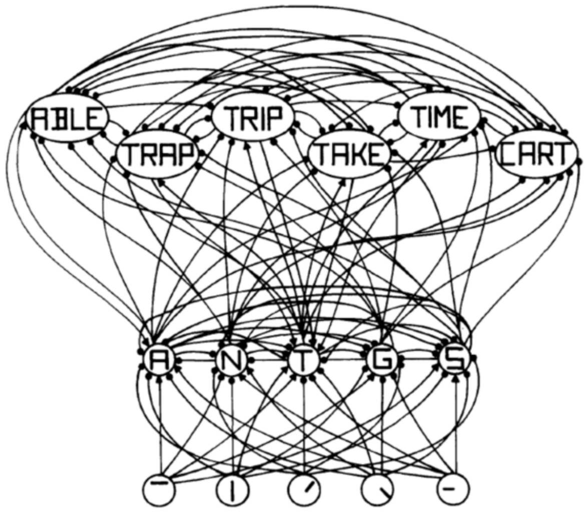

Figure 2.8: Interactive activation model mapping of visual features to lexical index (McClelland and Rumelhart, 1981, p. 380)

The activation of nodes is dependent on excitatory activation form neighboring nodes, where each node which is inactive is assumed to be at an activation value of zero or below, and every node which is active has a positive activation value. Inactive nodes do not influence their neighboring nodes, and excitatory and inhibitory activation spreads to either push the node to a level above or below their resting level. The letter nodes which are connected with excitatory connections to the visual feature level nodes are activated and send in turn activation to the word-level nodes they are consistent with (McClelland and Rumelhart, 1981). If then the visual feature nodes consistent with letter *T* in the first position of a word, are activated, the visual feature nodes of the *vertical* and *horizontal* lines feed excitatory connections to the letter node for *T*, among others. The level of activation of the nodes which the visual features are consistent with will be pushed over their resting level. The nodes which have received activation from the visual features are competing amongst each other, where the node with the highest level of activation *wins* and exceeds the activation level of the other nodes. The position in which the winning letter node *T*, which is in the first letter position of a word, then activates the words which are consistent with the *T* in their first position.

This process of the identification of T occurs simultaneous to the identification of the other letter nodes and their respective positions, where the word node which receives the highest amount of collective activations is recognized as the optimal in the word recognition process [3].

While the excitatory connections and inhibitory connections are active from a bottom-up perspective, the contextual features of the word, string of letters, are actively sending excitatory or inhibitory feedback to the word nodes. The knowledge of the words within a language give contextual input and will either send excitatory or inhibitory feedback to the letter levels. Both contextual knowledge, knowledge of a language and its words are thus interacting with the feature and letter levels in the process of word-identification.

2.2.3 Bilingual Interactive Activation Model

The Bilingual Interactive Activation (BIA) model shares its basic features with the monolingual predecessor, the Interactive Activation model. Both models are models of visual word recognition where visual word recognition is defined as the retrieval of orthographic representations from the mental lexicon, corresponding to the input letter string (Dijkstra and Van Heuven, 2002). The BIA model is concerned with aspects which are not applicable for its monolingual parent, the process of language selection. This question is seen in light of two main aspects of bilingual language processing; 1. Are candidates from both languages activated simultaneously or is only one language active in visual processing (language non-selective access vs language selective access), 2. Are the lexical representations of the languages represented in separate lexicons for each language or are they represented within a shared or integrated lexicon. ”*In an integrated lexical system competition or selection effects may occur between lexical candidates of both languages, whereas in two separate lexical systems competition effects are limited to candidates of one language only*” (Dijkstra and Van Heuven, 2002).

The language-selective access hypothesis, which assumes that a bilingual has two separate lexica which are selectively accessed depending on the input information (Kolers, 1963) is in direct competition with the language non-selective access hypothesis. The language non-selective access hypothesis assumes that both languages are simultaneously activated during the word recognition process. (Van Heuven et al., 1998, p.191) argue that the language-selective hypothesis must be discarded as soon as there is evidence for online cross-language effects which cannot be explained by weak stimulus lists and experimental flaws. They further argue that the language non-selective hypothesis can explain the absence of cross-language effects in several ways: the task effect, assuming that some task are less sensitive to cross-language effects, the difference in degree of proficiency as well as the insensitivity of certain stimuli in a particular context. The BIA model implements the language

[3] McClelland and Rumelhart (1981) consider only up to four letter words, as these could be accounted for by the program designed to test their hypothesis.

non-selective access hypothesis within and integrated lexicon in its framework.

The BIA model follows the basic functions of the interactive activation models framework and adds an extra representational layer of language nodes. The feature input feed activation through excitatory connections onto the letter nodes which are compatible with the feature input at the respective feature position. The letters excite words in which the activated letter node is present, in each of the languages, while all other words are inhibited. All words are connected to each other through inhibitory connections, irrespective of the language they belong to. Cross-language inhibition is implemented into the BIA model through the language nodes, which are assumed to be a collective of factors affecting word recognition processes of a bilingual. The language nodes are inhibitory, where connections to a language are suppressed in the inappropriate lexicon, thus the activated word nodes from the same language send activation on to the language node which sends inhibitory feedback to all word nodes in the other language (Dijkstra and Van Heuven, 2002, p.177).

Dijkstra and Van Heuven (2002) argue that there are four main functions of a language node, where the first two are linguistic representations and the last two are non-linguistic functional mechanisms (Dijkstra and Van Heuven, 2002, p.177). The language nodes are assumed to collect activation from lexical representations within one language. The collective activation implies that speed of activation of each language node depends on the number of items connected to that node, where top-down effects such as between trial priming effects (Grainger et al., 1992) or if decisions are affected by bottom-up mechanisms such as same/different language membership of consecutive items (Dijkstra and Van Heuven, 2002, p.177).

The non-linguistic features of the language nodes are language filters and contextual pre-activation. The language nodes function as mechanisms modulating language activation relative to performance, thus accounting for differences across experiments, functioning as a filter, rather than an all-or-none language switch. The language pre-activation function can collect contextual data from outside the word recognition system. The language node can account for potential top-down effects on the lexical identification system originating form e.g. the expectations of the participant with respect to language(s) and input material to be processed. "*For the last three functions, the BIA model assumes that (by inhibiting non-target language words) the language nodes were able to facilitate the selection of words from the target languae after non-selectiv access took place, but could not enforce language selective lexical access from the very beginning of word recognition. Indeed, simulations show that even with string pre-activation of the language nodes and string top-down effects to the word level, word candidates form the suppressed language can often be recognized*" (Dijkstra and Van Heuven, 2002, p. 177).

2.2.4 The BIA Model Evaluation

In an evaluation of the BIA model by Dijkstra and Van Heuven (2002) a number of strengths and weaknesses were pointed out. The BIA model assumes a certain amount of competition between orthographic neighbors, defined by Coltheart et al. (1977) as *any word differing by a single letter from the target word respecting length and letter position (Dijkstra and Van Heuven, 2002, p.178)*. Neighborhood effects seem to arise during word recognition, where it is assumed that an integrated lexicon will be affected by orthographic neighbors by both languages, when language access is non-selective. In a separate lexicon, only neighbors from the target language are assumed to be active during the word recognition process. A series of progressive demasking and lexical decision tasks Van Heuven et al. (1998) indicate that neighbors of the target are activated for both languages, and the effect of these neighbors are language dependent. An increased number of orthographic neighbors of the target language consistently provided inhibitory effects when the target was Dutch and facilitatory effects for English target words, in experiments with unbalanced Dutch-English bilinguals (Van Heuven et al., 1998). The BIA models assumption that bilingual word processing is language non-selective with an integrated lexicon, seems to account for these findings, when considering the subjective frequency and an asymmetric top-down inhibition (Dijkstra and Van Heuven, 2002).

In cross-linguistic masked priming experiments Bijeljac-Babic et al. (1997) found evidence of target word responses were inhibited when target and prime words were from the same language and orthographically similar, whereas prime and targets which were orthographically dissimilar were not. When prime and target words were from different languages, inhibitory effects were found to be dependent on language proficiency of the prime language. Results indicate that facilitory effects of orthographic similarity were suppressed by inhibitory effects of lexical competition (Dijkstra and Van Heuven, 2002). The BIA models assumption of an asymmetrical top-down inhibitory effect assumes, in accordance with the findings of Bijeljac-Babic et al. (1997)'s study, a larger within-language inhibitory effect and a tendency towards inhibitory effects in between-language conditions (Dijkstra and Van Heuven, 2002, p.179).

Language effects of previous items (Van Heuven et al., 1998; Von Studnitz and Green, 1997) indicate that in trials where the prime and target language are different were significantly slower than when prime and target belonged to the same language. These effects can be attributed to interaction of the language nodes within the BIA model, where target word recognition is affected directly by the language of the preceding word (Dijkstra and Van Heuven, 2002).

The BIA model seems then to be able to account for neighborhood effects, language proficiency and form priming and effects of previous languages. However, some shortcomings of the original BIA model need to be considered (Dijkstra and Van Heuven, 2002, p.181):

- *there are no phonological or semantic representations in the model;*

- *the representations of interlingual homographs and cognates is underspecified;*
- *representational and functional aspects with respect to the language nodes are condounded;*
- *there is only very limited account of how non-linguistic and linguistic context affect bilingual word recognition;*
- *there is no detailed description of how participants perform a particular task, for instance lexical decision;*
- *the relationship between word identification and task demand is underspecified.*

2.2.5 The Bilingual Interactive Activation Plus Model

The Bilingual Interactive Activation pluss (BIA+) model is a modified extension of the BIA model and incorporates lexical semantic and phonological input as well as orthographic into the word recognition process. In addition, the BIA+model takes a level of representation which encodes language activation into account. The BIA+ model is the first model of its kind to incorporate phonological features as well as visual features and semantic representations into a combined model of bilingual language representation and processing. The phonological aspects of the BIA+ model are based on the spreading activation models such as the WEAVER++ (section 2.2.1) and proposes that similar processes of phonological activation and lemma selection are part of the word-recognition process in addition to the process of visual word recognition, see section 2.2.2.The visual word-recognition processes as proposed by (McClelland and Rumelhart, 1981; Van Heuven et al., 1998), are incorporated into the BIA+ model with marginal changes in order to be able to merge the phonological and semantic processing systems into a combined structure.

The BIA+ model proposes, in line with the BIA model, an initially language non-selective access process with an integrated lexicon. The main distinction is that the BIA+ model assumes two distinct systems: a word identification system and a task/decision system.

The BIA+ model assumes that there is a higher level processing structure which keeps track of the language input, where the given language is at that point at a higher level of activation than another. The input language thus feeds excitatory connections to the lexical and phonological components of the given language and inhibitory connections to any other language. The extension to the BIA model in this regard is that it implements the assumption of cross-linguistic orthographic similarity to effect cross-linguistic phonological and semantic overlap.

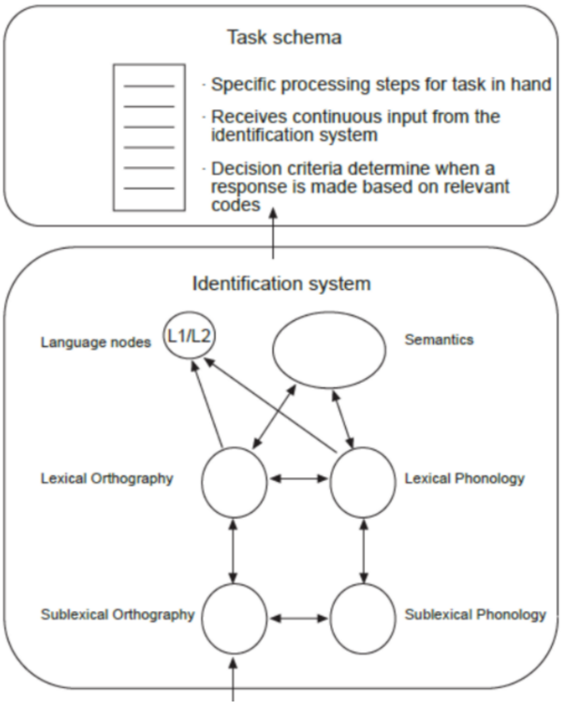

Figure 2.9: Bilingual interactive activation model, task schema and identification system Dijkstra and Van Heuven (2002)

Orthographic Codes

The word identification system deals with orthographic codes, where the first steps of the orthographic activation within the BIA+ framework are equivalent to the BIA model. A number of lexical candidates are activated depending on their feature activation from the input. The similarity to the input string, resting level, frequency of use as well as subjective frequency and language proficiency are conjointly determining the activation level of the orthographic input. The second language representations are assumed to be at a, subjectively, lower activation level than those of the first language. The activated orthographic representations are in turn activating the corresponding semantic and phonological representations, where similarity of the input word to the internal lexical representation, rather than the language membership, determines their activation (Lemhöfer and Dijkstra, 2004). The level of activation is dependent on the overlap between the input string and a representation in the mental lexicon, where the overlap determines the level of activation. The number of activated orthographic candidates is determined by factors such as the neighborhood density and frequency of the target word, as well as its within- and between-language neighbors (Dijkstra and Van Heuven, 2002, p.182–3). "*For interlingual homographs and cognates with different orthographic forms (and therefore two representations) across two languages, the degree of code activation of the non-target reading also depends on the degree of cross-linguistic code overlap*"(Dijkstra and Van Heuven, 2002, p.183). The BIA+ model predict that the size of cognate and interlingual homograph effects depend on their degree of cross-linguistic overlap , in order to account for position-specific mismatches, the letter to word connections in the BIA+ model must be differentiated with respect to position, or a new letter coding scheme must be introduced. Font (2001) argues that "Neighbor cognates" are still facilitated but significantly less so than identical cognates. Neighbor cognates differing at the end of the word (*TEXTE*, *TEXTO*) were facilitated more than neighbor cognates differing inside the word (*USUEL*, *USUAL*). Facilitatory effects for the latter type of cognate disappeared and effects tended toward inhibition when such cognates were of low frequency in both languages (Dijkstra and Van Heuven, 2002, p.183).

Phonological and Semantic Codes

The BIA+ model assumes a temporal delay for phonological and semantic representations to be activated over sublexical and lexical orthographic representations. (Dijkstra and Van Heuven, 2002) argue that, because activation depends on (among other factors) subjective frequency, the phonological and semantic coding in the second language would be delayed relative to the first language coding. The temporal delay assumption consequently argue for a cross-linguistic effects will generally be larger from first language to second language, than in the opposite directions and that the absence of phonological and semantical effects for different words could occur if tasks allow for faster response to first language codes (Dijkstra and Van Heuven, 2002, p.183).

Interlingual homographs and cognates

There are several reasons for using interlingual homographs in cross-linguistic studies. If the recognition of the English reading of the homograph (LIST) by Dutch-English bilinguals is affected by the Dutch reading, then response latencies should be different from those to one-language control items that are matched to the interlingual homograph frequency, length and other characteristics (e.g. MILK). For instance, the requirement of selecting either the English or the Dutch reading of a homograph might induce inhibitory effects relative to a control. However if recognition proceeds in a language selective way then no RT differences between homographs and controls would be expected, because the Dutch reading of the interlingual homograph would not be activate at all and would not affect lexical selection based on the English lexicon. The BIA model assumes that a homograph is represented in the mental lexicon twice, once for each language (Van Heuven et al., 1998). Each representation has a resting level activation depending on this frequency of occurrence in the language that is belongs to. Furthermore, these representations compete with words of both language in standard fashion. Using asymmetric top-down inhibition, forms patterns of correct responses in percentages for homographs and control words in the three frequency condition. The study by Dijkstra et al. (1999) suggests that the relative frequency of the interlingual homographs rather than only its form similarities may cause facilitatory effects. This would indicate that not only form similarities are influencing the reaction time data for interlignual homographs and cognates, but also their relative frequency in the two languages. The BIA+ model assumes that interlingual homographs have to separate lexical representations, although if the same holds for cognates is not specified in the current version of the model.

Chapter 3

Method

As the field of psycholinguistics has grown a number of experimental procedures have emerged in order to capture the process(es) which govern our mental lexicon(s). Lexical decision tasks within the priming paradigm have become a frequently used experimental design in psycholinguistic research. One of the reasons why priming has become such a well-established form of research is that is requires less experimental equipment and thus is less expensive than other popular research techniques within the same field, such as fMRI and ERP. The priming paradigm has been used in research over a long period of time as the collection of response time to different stimuli has been directly linked to the processing effort and thus can provide insight into the mental processes and language connections. Within the priming design, it is possible to investigate a large number of factors which could possibly give insight into the inner workings of languages and how these may be connected. This chapter will provide an outline of the experimental procedure that were used in the experiments of this study, as well as a description of the equipment used and the overall design of the experiments. The experimental stimuli will also be introduced in more detail.

3.1 Priming as a measure of lexical access

The initial idea of priming referred to the carryover effects between tasks, it was first implemented by Karl Lashley in 1951 as Lashley was "*dealing with problems of how serial response sequences, such as in speech production, flow so quickly and apparently effortlessly*" (Bargh, 2014, p211). Lashley further argued that "*there had to be a mediating state intervening between the act of will or intention and the production of the intended behavior, which assembled the action into the proper serial sequence*" (Bargh, 2014, p211). Subsequent word association experiments conducted by Storms (1958), found an effect of "*the recent use of a concept in one task on the probability of its usage in a subsequent, unrelated task*" (Bargh, 2014, p212). These tasks showed that participants were more likely to use words from an initially shown word-list in a first (learning) task in a second task (free association), even though participants failed to recall them at the end of the first task (Bargh, 2014, p212). Priming has later been defined as an implicit memory effect in which exposure to one stimuli affects the response to a subsequent stimuli.

Though the idea of priming has been around since the 1950's, it was first implemented in a lexical decision task by (Meyer and Schvaneveldt, 1971). The study by Meyer and Schvaneveldt (1971) showed that participants reacted faster in a lexical decision task if word pairs were commonly associated (BREAD-BUTTER), rather than un-associated (BREAD-DOCTOR). A wealth of studies has in the following years provided insight into a number of different priming effects. The facilitatory or inhibitory effect between the prime and target pairs has been contributed to lexical access. Where facilitatory effects have been found, one can reason that this indicates a shorter pathway between the prime and target words, than for the instances where no facilitatory effects or even inhibitory effects were found.

The current study uses an unmasked priming paradigm in order to investigate if there is evidence for a reduction in reaction time for either meaning related words or form related word within lexical decision tasks. An unprimed lexical decision task was conducted in order to investigate if the priming effects found are actually pure priming effects, as one of the problems within this type of research is the matching of word pairs.

Masked and unmasked priming

Simply seen, the procedure of priming is a measure of processing speed for two words that differ on some potentially relevant variable (Forster, 1998, p.203). One of the problems with cross-linguistic primes is however, that these always differ in more than one aspect, where the main difference is their language membership. The variable of interest in a given cross-linguistic priming experiment is therefore not as easily separated, and thus the possible effect of processing speed in regards to the intended variable are more difficult to isolate. This may be one of the reasons for the many priming studies, as the possibility to match words across languages and see how these are connected, or where inhibitory effects can be seen are many. However, the problem of matching words across languages as well as a possible solution to this problem will be discussed at a later stage.

A priming tasks can either be *masked* or *unmasked*. Both the masked condition and the unmasked condition have been used in a large number of lexical decision tasks. The main difference between the tasks is the addition of a mask between the prime and the target. Within a masked lexical decision task the prime and target are presented visually with a very short priming interval (about 50-60ms) (Forster, 1998, p.204). A masked priming sequence would thus be presented in the following sequence:

mask ##### (500ms)
prime stimuli (50ms)
TARGET STIMULI (500ms)

Forster argues that the prime, within the masked priming paradigm is virtually invisible for most subject because the prime is sandwiched between a forward pattern mask and the target stimuli Forster (2015). The hope of this priming paradigm is that the short exposure may offer insights into the effects of processing which are free of extralinguistic influences as the prime never reaches consciousness (Forster, 1998, 2015). However, there are cases where participants can report what the prime is, even with the limited exposure to the prime and the mask in place.

The unmasked priming paradigm as proposed by Meyer and Schvaneveldt (1971) has continued to be a commonly used experimental technique. The prime in the unmasked condition is often visible for a longer period of time about 100-500 ms. An unmasked priming sequence would be as following:

prime stimuli (100ms)
TARGET STIMULI (1000ms)

However, a large number of different stimulus onset asynchronies have been used over the large amount of available studies using this experimental technique (Altarriba and Basnight-Brown (2007)). In both cases, the priming is essentially the facilitation of effect of a linguistic stimuli on the recognition of a subsequent target word, where the effect is measured in reaction time.

3.1.1 Lexical decision task

A lexical decision task can be defined as ”*an experimental task in which subjects have to decide as fast as possible whether a given letter string is a word or not*” Dictionary.com (2015). Lexical decision tasks are often used in both psychological and psycholinguistics studies. They evaluate *yes* and *no* answers to a simple question: is the TARGET letter string a word? Within this study three variation of the task will be presented:

- **Experiment 1** Is the given letter string a Norwegian word?
- **Experiment 2 and 3** Is the given letter string an English word?
- **Experiment 4-8** Is the given letter string a Norwegian and/or an English word?

The three variations of the lexical decision task are all implemented in the same open priming paradigm, where the target and the prime are matched for category across two languages (Norwegian and English).

The individual baseline experiments are a series of the three variations of the lexical decision tasks, where each experimental block asks the same question as one of the three variation mentioned above. The baseline experiments are unprimed lexical decision tasks, although these experiments are presented within the same experimental paradigm as the priming experiments.

The lexical decision tasks which will be examined in the following chapters are *cross-linguistic* lexical decision task. This introduces the possibility to evaluate aspects of how two languages are connected.

In order to get a measure for lexical reaction, it is important to match the number of words which require a *yes* answer to the number of non-words requiring a *no* answer, see Altarriba and Basnight-Brown (2007) for a thorough examination of the word/non-word ration within lexical decision task experiments.

3.2 Methodological and procedural specifications

3.2.1 Experimental Equipment

The same experimental design was used for all experiments. The first four experiments are designed on a macbook pro, using SuperLab 4.5 to create the experiments and Cedrus Data viewer 2.0 to collect and organize the results. The baseline experiments as well as experiments 5-8 are designed on an ASUS Zenbook model UX31A notebook PC, using SuperLab version 4.5 for design and execution of the experiment and Cedrus Data Viewer 2.0 to collect and organize the results. The reaction times were collected through a response pad RB-530.The response pad (RB-530) is an accurate way of collecting reaction times, as it offers a 2-3 millisecond reaction time resolution Cedrus (2015). A keyboard would in contrast only offer a resolution between 10-35 millisecond, depending on the type of keyboard. The experimental stimuli were presented on a pink flat screen TV that connected to either a macbook pro or an ASUS PC, depending on experiment.

The lab in which the experiments were conducted is a small room, including only a chair and a desk with a TV to present the stimuli on and a response pad to collect the answers. The only thing in the participants' direct sights was thus the TV-screen and the response pad. The lab has a small window, through which the experimenter is able to follow the proceedings of the experiment. All participants are alone during the experiment as to limit distractions. All other distracter items such as mobile phones etc. were not allowed inside the lab during the experiment.

3.2.2 Experimental procedure

The experiments follow the same pre-testing and testing procedure. Before any participant was allowed to enter the experiment a few prerequisites needed to be met as part of the 3.2.2. Participation in any of the experiments in this series was completely voluntary and not rewarded. Every participant was informed at the beginning of the experiment that they may leave at any point during the experiment and that an experimenter would wait outside the

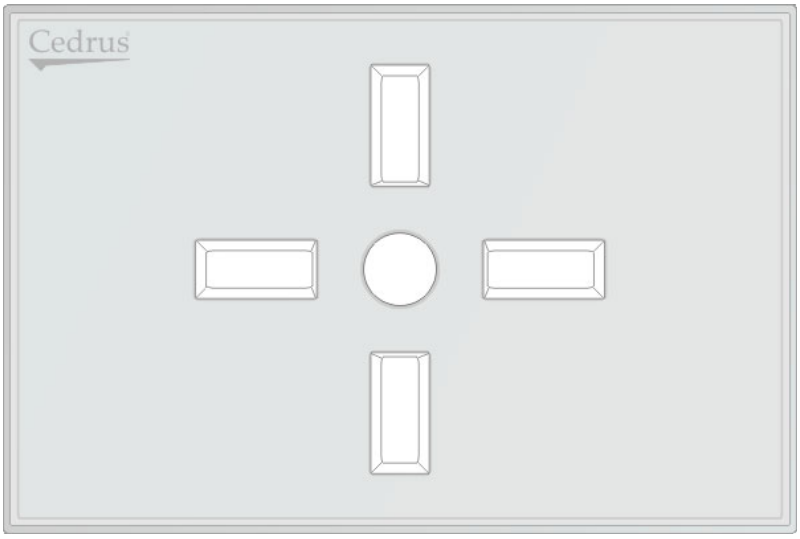

Figure 3.1: Serial response pad RB-530 was used to collect all reaction times for all of the following experiments. The leftmost button had a red label and the rightmost button a green label indicating wrong and right answers respectively

door at all times. Participants were tested individually and were not allowed to communicate with waiting participants after the experiment was finished. Before entering the experiment participants were asked to fill out a self-evaluation questionnaire.

For the duration of the experiment participants were alone and asked to fulfill the given task to the best of their abilities. Participants were told only to focus on words in upper case letters, although no additional instructions were given from the instructor. Every experiment started with a detailed instruction of the task.

The instructions were presented on the testing screen, where participants were allowed time to read through instructions at their own pace. In order to start the experiment the participants were instructed to press any button to continue, and to do so only when feeling confident to start the test. The first part of the experiment consists of a trial round, where participants are given feedback on 6 prime-TARGET pairs, in par with the following experiment. After the 6 prime-TARGET pairs with feedback, the participant are informed to start the experiment if they feel confident that they have understood the instructions. This was to ensure that all participants had the opportunity to ask the experimenter if anything was unclear. After completing the experiment, participants were free to leave.

Pretesting

A number of pre-requisites needed to be met before participants were able to enter into the experiment. A participants reading skills needed to be normal, thus excluding participants with dyslexia or other reading disabilities, such as uncorrected bad eye-sight. For all experiments except for experiment 3, Norwegian should be their dominant language (L1). Participants for experiment 3 are Norwegian beginner-learners with a non-Scandinavian dominant language.

A minimum of high-school English studies was required for all participants. Participants suffering from epilepsy were excluded as well, due to their own safety as the flickering of the screen could induce an epileptic seizure.

If the pre-requisites were met, the participants were asked to fill out a self-evaluation form. The participants were to indicate their reading proficiency in English and Norwegian on a scale from 1-10, scoring their skill level as competent (towards the higher end of the scale) if they feel that reading newspapers and/or academic textbooks is easy. They were asked to indicate how often and through what medium they use their English knowledge (daily, once a week, etc. and television, reading, speaking etc.). If they know any other languages and if so, which languages and if they are more or less dominant than English.

3.2.3 Experimental Design

All experiments were divided into blocks and consisted of 3 different types of blocks: an introduction block, a practice block and at least one experimental block. The baseline experiments differ from experiments 1-8, with regard to the number of experimental blocks. Experiments 1-8 all include only one experimental block, whereas the baseline experiments include 3 separate experimental blocks.

The first block of the experiment is an introduction block, where the type of lexical decision tasks is explained. The second block is a test block, where the participants understanding of the instructions are examined.

Within the test block, feedback on right or wrong answers are given, a total of 6 word targets and 6 non-word targets are tested in this block. The experimental block follows the test block, within this block, no feedback on correct or incorrect responses are given. During the test block the participants need to answer *yes* (green button) or *no* (red button) to a set of words and non-words. There are 6 trial in the test block, where the participant is given feedback on correct and incorrect responses. If the participant's response in incorrect, the same trial is presented again, until the correct response is given. After the trial block, the participant is informed that the experiment will start and to press any button in order to begin. In the experimental block follows the same pattern as the test block, however, the correctness of the participant's responses are no longer indicated.

Both the test block and the experimental block of experiments 1-8 follow the priming sequence as indicated in figure 3.2, where a fixation mask '*' is visible for 500ms, followed by a prime presented in lower case letters for 100ms, which is directly followed by a target, presented in upper case letters. The target is visible for up till 1000ms or until a response is given. Immediately after a response is given or the duration of the 1000ms is passed, the next trial starts following the same design. The baseline experiments follow the same specifications as given for experiments 1-8, differing only with regard to the prime. The prime in the baseline study is removed, as can be seen in figure 3.3.

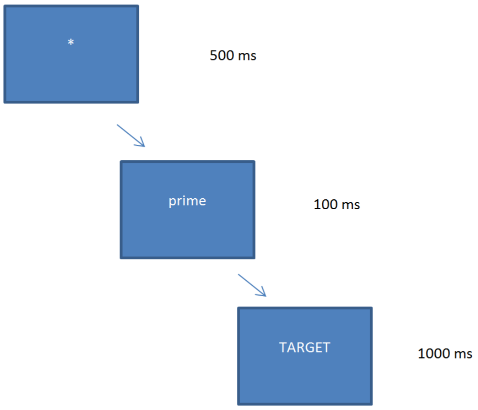

Figure 3.2: Priming sequence experiments 1-4 and 5-8

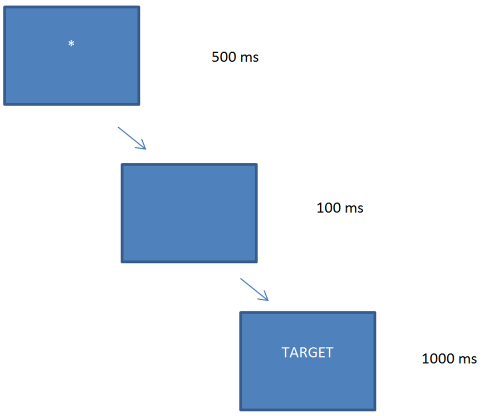

Figure 3.3: Priming sequence for baseline experiments (nullprime)

Experiments 1-4

The original design of the experiments contains a block of 40 Norwegian-English word pairs and a block of 40 non-words. The difference between experiments 1 and 2 is the direction of the prime and target pairs. While experiment 1 contains Norwegian targets primed by English only, experiment 2 is the exact opposite containing only English target primed by Norwegian. Experiments 2 and 3 are identical in their design, only differing with regard to the language proficiency of the participants. Experiment 4 was a mixed-target experiment where 20 words were Norwegian targets primed by English and 20 words were English targets primed by Norwegian. The non-words were primed either by English (experiment 1), Norwegian (Experiment 2 and 3) or a mix of Norwegian and English (experiment 4). All experiments follow the same procedure as outlined in 3.2.3.

Baseline

Within the baseline experiments there are a number of variations to the experimental design. Although all experiments follow the specifications as outlined in 3.2.3, the order of the experimental block varies. Each of the baseline experiments includes three separate experimental blocks. The experimental blocks are divided into a Norwegian target block an English target block and a mixed target block. Within all blocks, the prime is empty, such that the participant is looking at a blank screen for the duration of the prime (100ms). The blocks are presented in a different order to different participants. A short break is added between each experimental block.

Experiments 5-8

Experiments 5-8 follow the same specifications as outline in 3.2.3. The experiments are divided into two blocks, a baseline block and an experimental block. The baseline block is a mixed-language block where all 40 words in the stimuli list are presented in addition to the 40 non-words. A baseline was either presented before the experiment (experiments 5 and 7) or after the experiment (experiments 6 and 8). The baseline block was a mixed-language block with all 80 words and 80 non-words.

3.3 Experimental Stimuli

The same stimuli list is used across all experiments in order to investigate variations of form and meaning across the entire set of experiments. The stimuli consists of a word list with 40 Norwegian and English word pairs, such that each experiments contained 40 Norwegian words and 40 English words. The aim of the experiments was to examine form and meaning relations between Norwegian and English, the word-pairs were therefore divided into four categories;

- *cognates* (+ meaning, + form)
- *lookalikes* (- meaning, + form)
- *translations* (+ meaning, - form)
- *unrelated* (- meaning, - form)

Each of the four categories includes 10 word pairs and each word pair consists in turn of one Norwegian and one English word. The relations between the English and Norwegian words are determined by their form (orthography +/-) and their semantic relation (meaning +/-). The following sections will discuss the definitions of the categories and outline, if there is more than one commonly used definition, which of these was used.

3.3.1 Cognates

Cognates are becoming a well-established category of word relations in cross-linguistic literature, and are frequently used in studies within this field. There are, however, a number of different ways of defining cognates. Lemhöfer and Dijkstra (2004) defined cognates as words which are completely overlapping in orthography and meaning such as the English words *taxi* and *hotel*, which completely overlap with the Dutch words *TAXI* and *HOTEL*. Sáchez-Casas et al. (1992) however, defines cognates in two languages as words that share a common original stem, and exhibit a large degree of orthographic form and meaning overlap. Where the degree of meaning and form overlap can vary, such that some share many of their letters e.g. the English word *rich* and the Spanish word *RICO*, and some do not e.g. *tower* (English) and *TORRE* (Spanish), and there are some where the correspondence in meaning is not exact, e.g. *paper* (English) and *PAPEL* (Spanish) Sáchez-Casas et al. (1992).

In the following experiments, an adaptation of the definition given in Sáchez-Casas et al. (1992) is adopted. All words classified as cognates are similar in orthography, although non-identical in spelling across Norwegian and English, also referred to as non-identical cognates. The (non-identical) cognates used in the following experiments are closely matched for number of letters within a word pair, are similar in orthography and phonology and possess the same number of syllables. Although Sáchez-Casas et al. (1992) include in their definition of cognates words which are not identical in meaning, this is not the case for any of the 10 word pairs within this stimuli list. There may however be cases where one or both of the words in a pair could possess an additional meaning, the main use of both words is judged to be the primary use.

3.3.2 Translations

Generally, translations are distinguished from cognates in one regard, orthography. Translations do not share the same or similar spelling across two languages. Where cognates have a one-to-one correlation between the languages, this does not apply for most translates. Where the Norwegian *papir* can be translated into English as *paper* only, the English *paper* can be translated into Norwegian as *papir* (paper), *avis* (newspaper), *oppgave* (exercise, exam) among others. Another problem of this kind can be found where words have multiple translates in both directions.

A number of different methods have been employed to find a suitable translation pair for the purpose of experimental studies within the psycholinguistic field. In a study by Dijkstra and Van Heuven (2002) students were asked to translate a list of words in German and English, picking those translation pairs that were most frequent among the student translations. The word pairs that are classified as translations within this study are classified as such along two criteria. Translations within this study are both completely dissimilar in spelling and matching for word-length and frequency.

3.3.3 Lookalikes

The category of lookalikes, often called false friends or interlingual homographs, faces the same problem as we saw with cognates and translations. Their definitions vary from study to study. Lemhöfer and Dijkstra (2004) assumes that false friends are identical in spelling and do not share any meaning similarities, such as the Dutch *die* (those) and the English *die*, which share the same orthography, although mean completely different things. It is however not always the case that words referred to as interlingual homographs are words which completely overlap in orthography used to illustrate this category of words. Within this study, the category *lookalikes* refers to orthographically similar, although non-identical, words which do not share the same meaning. The lookalikes included in this study are matched for word length, number of syllables and frequency across languages.

3.3.4 Unrelated

The unrelated word pairs in this study share neither meaning nor form similarities. This category functions as a baseline, as there should be no priming effect between unrelated words. The word pairs in this group should bear no relation to each, the words within a word-pair should not share meaning, nor orthographic similarities, phonological similarities or share close semantic relations. Because this group of words does not share meaning or form overlap, it is possible to compare the reaction times in this group to those of the other three groups within this experiment in order to see if form and/or meaning affect reaction times.

3.3.5 Non-Word

Supplementing the 40 word pairs, an equal number of non-word targets are included in the experiment. The non-words are equal across experiments 1-8, although their prime differs across the different variations of the experiments. Altarriba and Basnight-Brown (2007) suggests that a non-word ratio (NWR) of 50/50 is needed to avoid a bias in one direction or another, within lexical decision experiments.

All non-words included are made up words and should not be a word in either English or Norwegian, nor any other language that the students participating in LING301 course know. The non-words follow the basic syllable structure of Norwegian and English, although they should not be possible words in either English or any of the two Norwegian written languages (Bokmål and Nynorsk).

Non-words are either primed by English existing words or Norwegian words, depending on the experiment. The non-words in experiment 1 are primed by English, in line with the priming direction of that experiment and the non-words in experiment 2 and 3 are primed by Norwegian words. Half of the words in experiments 4-8 are primed by English and the other half are primed by Norwegian, such that the same ratio of Norwegian and English primes are present in the non-word group as were found in the word-pairs.

Within the baseline study, the baseline 1 block of the experiment included the same word and non-word pairs as those found in experiment 1 and the baseline 2 block included the same word and non-word pairs as those found in experiment 2. The baseline 3 block was extended to include 40 additional non-word pairs, such that a total of 80 non-words were present in this condition. This was done in order to maintain an equal amount of non-word targets as word target. Within the baseline 3 block 40 non-words were primed by Norwegian and 40 non-words were primed by English.

3.3.6 Frequency

All word pairs are matched for frequency. The frequency estimates were found using a restricted google search, limiting responses to the given language. Using a google estimate as a measure for frequency poses a few problems, although matching frequencies in any other way is also problematic. Although there are corpora which can be used to estimate frequencies in a more controlled manner for English, the same is not possible for Norwegian as the largest corpora is the newspaper corpora, which would not be an accurate indication of frequency for the average language user.

Comparing word frequencies of Norwegian and English words posed a problem, because the Norwegian words frequencies were significantly smaller than the English frequencies. A log10 was estimated for each word and the word pairs were matched within a confidence interval. All words used in the stimuli list were within the confidence interval and should thus have a relative similar frequency.

Chapter 4

Results

The following chapter will describe a series of cross-linguistic priming experiments. The first experiments 4.1 were designed to test differences in the influence of form and meaning across Norwegian and English. The second set of experiments 4.2.2 were designed to test if the stimuli used in the first experiments influenced the results. As will be shown, the second set of experiments proved interesting results that indicates that the priming effect can be separated from lexical reaction time (LRT). The last set of experiments 4.3 investigate the findings of the mixed language experiment (4) in a more controlled setting.

4.1 First Experiments (1-4)

This section will outline the first four of 8 cross-linguistic priming experiment. Experiments 1-4 were conducted as part of the LING306 *Experimental Psycholinguistics* course during the fall semester 2014. The experiments were designed and carried out by 8 students in collaboration with the supervising professor, Christer Johansson. The aim of the experiments were to investigate form and meaning effects between Norwegian (Bokmål) and English.

In order to be able to compare language direction two variations of the same experiment were created: Experiment 1 (English Prime - Norwegian TARGET), Experiment 2 (Norwegian prime - English TARGET). Another experiment was added in order to see if beginner learners of Norwegian would be primed by Norwegian: Experiment 3 (Norwegian prime- English TARGET) - identical to Experiment 2 The last experiment is a bidirectional experiment included in order to be able to investigate the task specific differences (mixed vs single language) and if there was an interaction effect between languages within a mixed language design: Experiment 4 (20 Norwegian prime - English TARGET and 20 English prime - Norwegian TARGET)

The main goal was to investigate across all experiments, how form and meaning influence reaction time in lexical decision tasks, within the cross-linguistic priming paradigm. The cognate effect and the effect of form across interlingual homographs have been investigated to in recent studies (Lemhöfer and Dijkstra, 2004). This study aims to compared nonidentical cognates and nonidentical interlingual homographs (lookalikes) to translations pair which share no orthographic overlap. The setup of the experiments made it possible to look into a few other hypotheses:

- There is a difference in effect depending on the language direction (Comparing Experiment 1 and 2)
- There is significantly less of an effect for beginner learners (Experiment 3)
- There is an effect of presentation mode (Single language or mixed language target)
- There is a difference in reaction time between the two condition *form* and *meaning*

4.1.1 Experiment 1 Norwegian Target Lexical Decision Task

Participants were drawn form the student population at the Faculty of Humanities at the University of Bergen. Participation was completely voluntary, as incentive to participate free coffee was provided. Procedures of all four experiments followed the same outline as in 3. A total of 18 students were recruited for experiment 1. All participants were dominant Norwegian speakers and between the ages of 18 and 26. Two of the 18 participants did not meet the test criteria and were consequently excluded form the results.

Experiment 1 was a one directional experiment and contained English prime words and Norwegian or non-word TARGETs only. The experiment included 80 prime-target pairs in total of which 40 prime-target pairs were English (prime) - Norwegian (TARGET) and 40 English (prime) - Non-Word (TARGET) pairs. All word-pairs are matched for frequency. Responses times for all targets were collected although only word pair responses are discussed in results.

Results. Only correct answers of a word-word pair were considered in the analysis of reaction times. The 16 participants produced a total of 116 correct responses which were included in the analysis. An anova test of repeated measures for repeated measures of the reaction time data revealed significant results of the main effect [$F(1,15)=8.082; p<0,05^*$]. Results show a 44ms meaning priming and 643ms for the unrelated condition (Stremme et al., 2014).

Figure 4.1 shows an overview of the reaction times for all participants by category. Where the median value for each category, indicated by the line within each box. The box itself shows the likely range of variation (IQR) within the 1st to 3rd quartile, while the whiskers extending out in both direction indicate the range of variation. The whiskers above the box are indicating 1.5xIQR above the third quartile, and below the box indicate 1.5xIQR below the first quartile. Outliers are indicated by dots above or below 3xIQR of the third or forth quartile respectively (Hoffman, 2015).

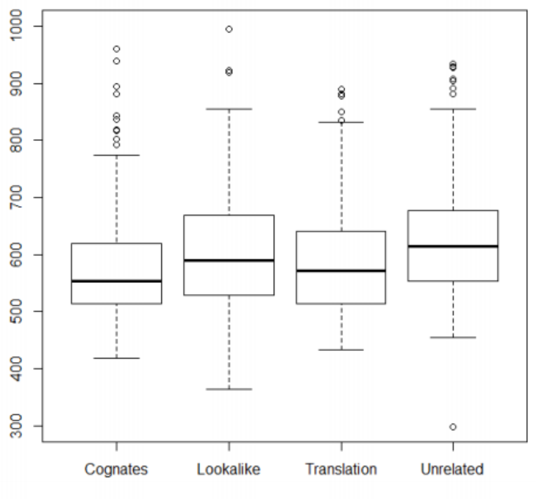

Figure 4.1: *Experiment 1* reaction time across categories

The median reaction times indicate that there is a meaning advantage, as both cognates and translation show a lower mean reaction time than lookalikes and unrelated. The category lookalikes show a larger variation than is seen in the other categories, indicating that there are larger differences in reaction time within this category.

4.1.2 Experiment 2 English Target Lexical Decision Task

Participants. Twenty dominant Norwegian speakers, drawn form the student population at the University of Bergen, participated in Experiment 2. The participation was completely voluntary and the procedure follows the outline as discussed in 3.2.2. One of the 20 original participants did not meet the experimental criteria and was excluded from the results.

Experimental 2 is designed with the reverse language direction as that of experiment 1. English primes are now targets and Norwegian target are now primes.

The stimuli list used in experiment 2 is identical to that of the stimuli list used in experiment 1, where the only difference is that the language of the the prime and target was reversed. Procedure and design of the experiment is identical for Experiment 1 and 2.

Results. Only correct answers were considered in the analysis of the collected reaction times. Where the anova of repeated measures reflected a significant main effect of meaning [F(1,18)=40.55;p<0.001***]. The data revealed a 46ms priming effect for meaning and 652ms for the unrelated condition (Stremme et al., 2014).

Figure 4.2 shows the distribution of reaction times for the four categories. Within the same parameters given for 4.1, an advantage for the meaning-related categories is found indicated by a lower median reaction time within + meaning categories (cognates and translations) than for the - meaning categories (lookalikes and unrelated). The lookalike show an even grater variation of reaction time in this experiment, indicating that it is more difficult to make a lexical decision task when there is orthographic overlap but no meaning relation in

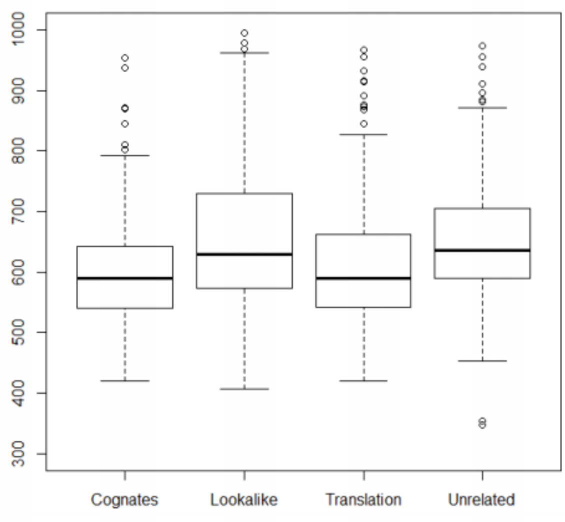

Figure 4.2: *Experiment 2* reaction time across categories

the L1-L2 task.

4.1.3 Experiment 3, English Target Lexical Decision Task Non-Native Speakers

Participants 22 subjects participated in Experiment 3. All participants were non-native speakers of Norwegian with English as a second but non-dominant language. Participants had various different first/dominant languages and had lived in Norway for less than one year, never having participated in formal Norwegian lessons. Participants were asked to evaluate their English through the same self-evaluation form, as those of experiment 1 and 2, where all participants deemed themselves fit to be able to read an English Newspaper, and used English every day.

Experimental design Experiment 3 was identical in structure to experiment 2, such that all primes were Norwegian and all targets were either English or non-words. Prime/target pairs were divided by a 100ms fixation point (*), where all primes appeared in lower case letters and all targets appeared in upper case letters. The SOA was 100ms and a target was either visible for 1000ms or until a participant response. The word-list and language direction of the prime/target pairs were identical to those of experiment 2. The instructions were presented, in English, on the screen which was used for the experiment. All participants were alone for the duration of the experiment, with an experimenter waiting outside.

Experiment 3 **Results**. An anova test of repeated measures of reaction times show a significant main effect of meaning [F(1,20)=27.7;p<0.001***] and revealed a 51ms advantage for meaning related primes over the unrelated condition, 686ms (Stremme et al., 2014).

Although indicating a higher mean reaction time than indicated in figure 4.1 and 4.2, the same pattern of results can be seen in figure 4.3. The median reaction times for the meaning

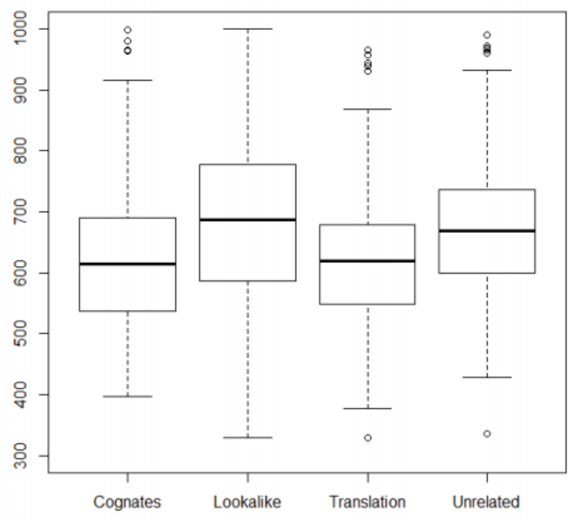

Figure 4.3: *Experiment 3* reaction time across categories

related words are the lowest across the four categories. The lookalike condition exhibits, in accordance with the previous experiments the same variance in reaction times. Indicating that even for the L3-L2 condition meaning related words are reacted to faster, and lookalikes create a very varied response pattern.

4.1.4 Experiment 4, Mixed Condition

Participants The mixed condition experiment included native-Norwegian students at the University of Bergen, who considered their English knowledge to be proficient at the same level as those of the previous experiments. Being able to read an English newspaper article to be the minimum of their reading and understanding of their less-dominant language, in accordance with their self-evaluation. Participation in the experiment was voluntary.

Experimental design Experiment 4 used the identical word-list as was used in experiments 1-3, a mixed set of target languages was used in order to examine whether a difference in instruction (identify a Norwegian/English word - single language vs identify a word in any of the two languages - multiple language) would influence the reaction times in either way across the same conditions. All categories were divided into 5 Norwegian targets (primed by English) and 5 English targets (primed by Norwegian). Each condition consisted of 5 prime/target pairs in each direction, while all non-word targets remained the same (primed by .5 Norwegian words and .5 English words). The stimulus onset asynchrony was 100ms, as in the previous experiments, precede by a 100ms fixation point (*) and the target was visible for 1000ms or until a participant response.

Results. The anova analysis of repeated measures of the reaction time data from the mixed condition experiment shows a main effect for meaning $F(1,18)=91.42$ $p<0.001$ (***). Indicating that there was a significant reduction of reaction times for meaning related words (cognates and translations) (Joahnsson and Stremme, 2014). These results are in accordance with the results found in experiments 1-3.

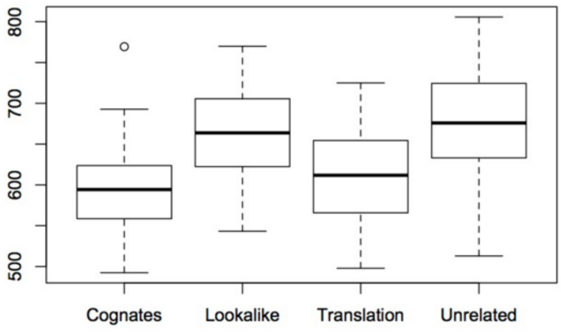

Figure 4.4: *Experiment 4* reaction time across categories

Figure 4.4 shows a clear difference in reduced median reaction time for the meaning related categories. These same pattern of results are found as those indicated in sections 4.1.1, 4.1.2 and 4.1.3.

4.1.5 Summary

Experiment	Intercept	Meaning	Form	Direction
1 16 subjects 611 observations	633.9	-44.2 **	-24.9	Nor
2 19 subjects 732 observations	651.5	-45.5 ***	-2.0	Eng
3 21 subjects 750 observations	686.1	-50.6 ***	7.5	Eng
4 21 subjects 750 observations	677.7	-65.4 ***	-10.7	Mixed
1a	690.8	-73.9	-	Nor
1b	657.7	-47.2	-	Eng

Figure 4.5: *Experiment 1-4* Summary

Figure 4.5 shows the results from experiment 1-4. A significant meaning effect for all experiments can be seen. This indicates that when the participants was primed with either a cognate or a translate the reaction time was faster for the target word. By comparison, form did not give a significant priming effect across the experiments.

In experiment 1 the meaning effect was measured to be 44.2ms faster than the overall mean reaction time. This experiment had the fastest overall reaction time of 633.9ms. Similar findings occurred in experiment 2 and 3 with 45.5ms and 50.6ms faster mean reaction time respectively. In experiment 4 where the target word was in mixed languages, we also can see a meaning effect with a 65.4ms faster mean reaction time.

A interesting result in experiment 4 was an interaction effect between meaning and direction. As can be seen in the table, there is a priming effect in the direction L2-L1, giving 73.9ms faster than mean reaction time. Overall the mean reaction time in experiment 4 was higher than in experiment 1 and 2. This could be due to a more complex task when experiment contained mixed target languages. It is slightly surprising that there is a larger meaning priming for L2-L1, than for the L1-L2 direction. One explanation for this may be that within the mixed model the more dominant language is highly activated and thus reducing the reaction times when the prime connects to the activated L1 through a meaning relation.

The form similarities are all non-significant, although for experiment 1 the form similarities between the English prime and the Norwegian target reduce the reaction time by 24.9ms. The opposite effect is found for the L3-L2 group, where the form similarities slow down word recognition by 7.5ms for the + form conditions.

4.2 Baseline

Traditionally an effect in lexical decision tasks is found by a difference in reaction times between a controlled baseline where prime and target are unrelated, as in experiments 1-4. This section will discuss potential issues with the stimuli used in experiments 1-4 as well as evaluating if the results found were due to priming influences or if there are other reasons for the reaction time difference for meaning related words.

Within Experiments 1-4 the category *unrelated* was used as a baseline, where both experimental conditions were absent (-), such that there was no meaning or form overlap between the prime and target words of the baseline category. This allowed us to compare the conditions where the influences of (+) form and/or (+) meaning were present with the condition where these were absent. The evaluation of the results of the experiments in chapter 4.1 show that there is a significant meaning related advantage. However, a few potential problems were observed whit closer examination of the stimuli and the experimental procedure. This chapter will discusses some of the potential problems. The main focus of the baseline study was to evaluate the assumption that the baseline category *unrelated* was adequate. Another important part of the baseline study was to evaluate if the potential problems found in the stimuli are significant and thus may have influenced the results. The first potential problem that will be discussed is that of translation frequencies. The second potential problem regarding the stimuli was that of letter number and if the processing time for each letter influenced the reaction times significantly. This section aims to investigate a few hypotheses:

- Translation frequencies influence reaction times across all categories
- The number of letters in one word can influence reaction times

- Each word has a subjective lexical reaction time

4.2.1 Translation Frequencies

The general frequencies of all words, across all categories, were assumed to be well matched for each word pair. However, the differences in reaction times within categories ... further investigation. One of the potential influences which needed further investigation was the number of translations[1] and the frequencies of these.

Translation pairs such as *GUTT-BOY* and *TICKET-BILLETT* were assumed to be one-to-one translates of each other. The English word *BOY* stands in a one-to-one correlation with the Norwegian translation *GUTT*. The Norwegian *GUTT* can however be translated into both the English *BOY* and *LAD*. This difference in the number of translations occurred in both directions. For example he English word *TICKET* can be translated into the Norwegian *BILLETT*, as well as *BOT* (to get a ticket).

The translations of the cognates are, with two exceptions, all one-to-one equivalents. The word pairs *RIS-RICE* and *PAPER-* are the only exceptions, where each corresponds to more than one translation in one direction. The Norwegian word *RIS* can be translated into English either as *RICE*, *CRITICISM* and/or *SPANKING*. The English *PAPER* can be translated into Norwegian as *PAPIR* (sheet of paper), *AVIS* (newspaper), *OPPGAVE* (assignment) etc. This suggests, that there might be a discrepancy between the two words that have more than one translate, although only one cognate in both cases.

Further exploration of the translations within the categories that are not related by meaning *lookalikes* and *unrelated* suggest that the found discrepancy between the number of translations from English to Norwegian and vice versa are found here as well. Though these categories face an additional problem. The list of lookalikes and unrelated words suggest that some self-priming may have occurred during the compilation of the word list.

The category *lookalikes* includes, word pairs such as *TOY-TØY* and *FABRIC-FABRIKK*, where there is a correspondence between *TØY* and *FABRIC*, even though they are not part of the same word pair, they share the same meaning. The English word *FABRIC* can be translated into the Norwegian *TEKSTIL*, *STOFF* and/or *TØY*. Indicating an overlap in meaning with the Norwegian word between the two word-pairs *TOY-TØY* and *FABRIC-FABRIKK*.

Within the *unrelated* category, another potential problem presented itself. A number of words within this category, both English and Norwegian, share a cognate with the other language. The word pair *SIRKEL-BANANA* consists of two cognates, although they words are not related to each other. The Norwegian word for *circle* is *SIRKEL* and *banan* is the Norwegian translation of the English *BANANA*. One identical cognate, *PRINTER* which has the same meaning and spelling in both languages and is pronounced almost identically.

[1]The number of translations are based on Clue dictionary, and that there may be other translations which are not accounted for, however, it is assumed that the translations found in this dictionary are the most commonly used, and others which may exist are not as frequently used.

Thus, both an identical cognate (PRINTER-PRINTER) and several cognates (for example BANANA and SIRKEL) that were thought to be excluded form the unrelated category are present. This oversight might be a reason for the differences in reaction times found within this category.

Altarriba and Basnight-Brown (2007)[p.3] suggests that the frequency of words is an important factor within cross-language priming studies and argues that word frequency is influential in lexical decision task and the frequency of primes influences priming effects. Although the word-pairs in experiments 1-4 are matched for frequency of the prime and target across all categories, it was suggested that there might be a slight advantage for words that have many or high frequent translations over words which have few and/or low frequent translations. There might be meaning advantages for words that have high frequent translations, that are not accounted for in the word list.

New Frequency estimates

A new frequency estimate was collected for each word using a restricted google search. The searches were done on the same network during business hours on a weekday in order to get a closely matched frequency estimate. However, the google search parameters are not very clearly defined and may need further investigation if these alone are to be used as an accurate proxy for lexical reaction time.

The frequencies for the English words should be within the confidence interval of $10^{8.08}$ and $10^{9.25}$, as they were for the first measurement. The Norwegian words should be within the confidence interval of $10^{5.34}$ and $10^{7.11}$ and thus match those of the first estimate. The new frequencies fall into the same confidence interval as the first estimates.

English mean log10 frequencies

- Cognates = 8.69
- Translates = 8.58
- Lookalikes = 8.53
- Unrelated = 8.59

Norwegian mean log10 frequencies

- Cognates = 6.73
- Translates = 6.47
- Lookalikes = 6.39
- Unrelated = 6.37

4.2.2 Baseline Experiments 1-6

The purpose of the following experiments was to evaluate if the large effect of meaning (65ms), the small effect of direction L1 to L2, and the small interaction effect of meaning and direction came from priming. This was done using the same experimental design as the previous experiments (1-4) [2], the main difference between the first four experiments and the baseline experiments was that all primes were replaced by null-primes. For the duration of the prime, the participants were shown a blank screen instead of a word as shown in 3.3.

Baseline 1 is identical to Experiment 1, except the removal of the (English) primes and Baseline 2 is identical to Experiment 2 except the removal of the (Norwegian) primes. Meaning that Baseline 1 included all 40 of the Norwegian target words and Baseline 2 included all 40 English words as targets giving one reaction time measure for each of the words in the stimuli list across the two experiments. The reason for including the Baseline 3 experiment was to investigate whether or not there were task specific influences even in the unprimed state. Baseline 3 is therefor a variation of the mixed language experiment (4). In order to get a matched baseline, the experiment was extended to include all 40 Norwegian and all 40 English words, such that the original experiment was extended form 40 targets (as experiments and baseline experiments 1 and 2) to include 80 target words, an additional 40 non-words were added as a counterbalance. In order to test for repetition effects, every participant participated in *Baseline1*, *Baseline2* and *Baseline3*. The order of presentation was mixed, to insure that the results were not biased. 6 orders of the baseline experiments were presented:

1. Baseline1 + Baseline2 + Baseline3
2. Baseline1 + Baseline3 + Baseline2
3. Baseline2 + Baseline3 + Baseline1
4. Baseline2 + Baseline1 + Baseline3
5. Baseline3 + Baseline1 + Baseline2
6. Baseline3 + Baseline2 + Baseline1

Participants. A total of 36 native Norwegian speakers participated in the baseline experiments, 6 participants for each order. Participants were dominant Norwegian speakers with second or third language English. All participants were students at the University of Bergen, and took part in the experiment of their own free will, without any compensation for their efforts.

procedure. Before the experiment started, participants were asked to fill out a self-evaluation form, indicating age, education, their use of English and their main language(s). The experiment was held in a separate room, where the participant was alone during the testing period.

[2] Experiment 3 is not included in the baseline study because it is identical to experiment 2

After the test the participants were asked to fill out a short questionnaire indicating of they remembered a list of words from the experiments.

4.2.3 Baseline Results

letter number

Processing time for each letter is not accounted for, as categories includes words between 3-8 letters. It might be the case that the shorter words have an inherent advantage over longer words, because they require less processing time. A Difference in the number of short vs long words became apparent as the word list was investigated more thoroughly. It is the case that the categories differ in amount of long words, where the unrelated category includes the highest number of words including more than four letters. This category does also include the only three syllable words.

Getting the most accurate interpretation of letter number on reaction time, only the first position experiments were considered. Mean RT by letter number:

- **3** Letters in the target: 592.1
- **4** Letters in the target: 598.9
- **5** Letters in the target: 602.5
- **6** Letters in the target: 622.0
- **7** Letters in the target: 615.1
- **8** Letters in the target: 617.5

These numbers indicate that the is a direct correlation between processing time and thus reaction times between the number of letters and the reaction time speed. This is not taken into account in the first experiments, as the mean reaction time for each word and thus category was not corrected for additional factors that could be influencing reaction times.

Assigning the unprimed words the same categories as these words belonged to within the stimuli list of the first four experiments, confirmed that words belonging to translation pairs (translates and cognates) were faster although there was no significant difference between cognates and non-cognates i.e. no cognate effect was found.

For the preliminary analysis the reaction times for the experiments in the first position were looked at. The table 4.1 below shows the mean reaction times for conditions in the first position (the first time any given participant encounters the word) and across all experiments:

The mean reaction times in table 4.1 indicate that there is an advantage for the meaning related categories both in the first position and across all experiments. The mean reaction times for all experiments are show in figure 4.6 below.

Category	First position	All
Cognates	586.62	566.17
Translates	594.62	565.56
Lookalikes	616.71	595.18
Unrelated	624.32	599.42

Table 4.1: *Baseline* Mean reaction times for experiments in first position and for all

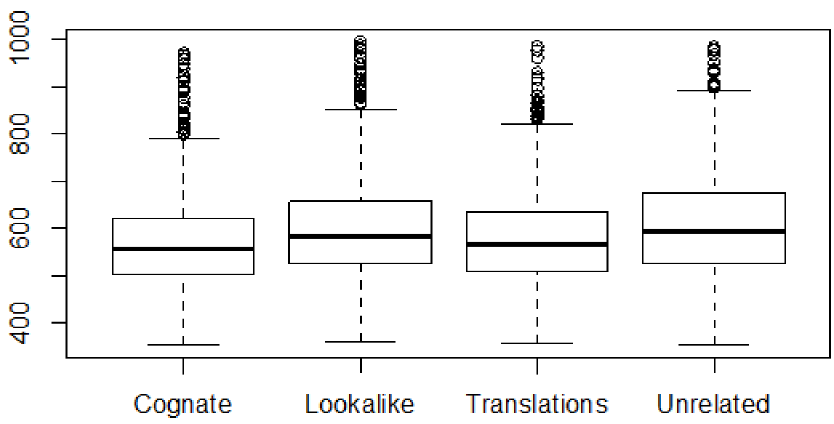

Figure 4.6: *Baseline* Mean reaction time across conditions for all positions

Figure 4.6 shows mean reaction times for all condition across all of the 6 variations of the baseline experiments. The figure indicates that even in the unprimed state, the same tendencies as those found in experiments 1-4 can be seen. The + meaning categories show a faster median reaction time than for the - meaning categories. This would indicate that not all of the variation seen in experiments 1-4 can be credited to priming. The difference in reaction times show that there are factors that influence reaction time, which were not accounted for in the first experiments.

Figure 4.7 shows the median reaction time after it is corrected for lexical reaction times. In other words, the variation has been removed, and as we can see there this leaves us with the same mean in the different conditions.

The variation in figure 4.6 is most likely due to lexical reaction times and other influences such as letter number and may even be influenced by frequency variation. Although many of these factors were thought to be accounted for, the variation in 4.6 indicated that there are factors which influence reaction time other than priming effects. The variation can thus be seen as lexical reaction time (including in this the frequency of words etc). Identifying the lexical reaction time is a useful tool because it allows us to correct the previous experiments for the individual words lexical reaction time leaving the priming effect as the only source of variation.

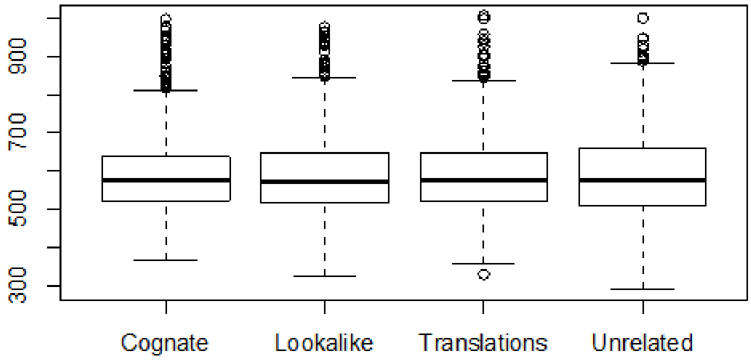

Figure 4.7: *Baseline* Mean reaction time across conditions for all positions after correction

Direction

The language direction in the unprimed task indicates that the L1 words are on average 17.8ms faster than the L2 words. Table 4.8 below shows the average correction factor per word across the two languages: *a* is English (L2) and *b* is Norwegian (L1) A two sample t-test shows a $t(71,96) = 2.91$; $p < 0.01$**, indicating that the language direction is a significant factor.

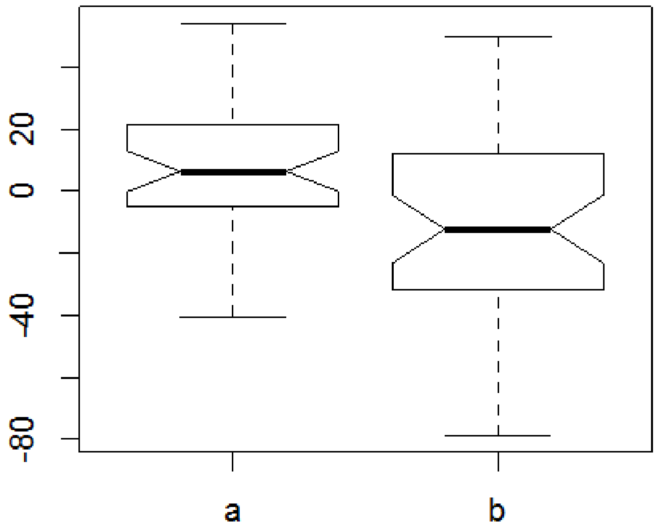

Figure 4.8: *Baseline* Correction factor across directions *a* English and *b* Norwegian

Outliers

The between category comparison indicates that there is a general tendency for cognates and translations to be reacted to faster. However, and interest in looking into the words which consistently fell outside the scope of two standard deviation was present. One assumed reason for this may be the influence of lexical neighbors or high-frequent translations not accounted for as the words-list was created. Before the baseline experiments were completed a number of words were seen as candidates to become outliers, such as words with high frequent translations, mainly regarding words in the *lookalike* and *unrelated* categories or words with a large number of letters.

Table 4.2 shows the distribution of words which are either reacted to faster (-sd) or slower (+sd) than average, across language and categories.

NOR	Category	+sd	-sd	ENG	Category	+sd	-sd
1-10	lookalike	3	0	41-50	lookalike	4	0
11-20	unrelated	2	0	51-60	unrelated	2	0
21-30	translation	0	2	61-70	translation	1	3
31-40	cognate	0	4	71-80	cognate	0	4

Table 4.2: *Baseline* Outliers +sd and -sd by language and category

Table 4.2[3] shows that the words which are generally reacted to slower (+SD) belong to the categories *lookalikes* and *unrelated* and those reacted to faster than average (-SD) belong to the categories *cognates* and *translations*. This holds for both Norwegian and English words and is in line with the findings reported in the previous sections.

The tables 4.3 and 4.4 below, show the words reacted to slower and faster respectively. Indicating both language and the number of letters of each of the words that fell outside of the standard deviation.

Median over sd (slower RT):

The general tendency of the slower words is that these include larger number of letters and do not have any high-frequent translations, either included in the experiment or outside the scope of the word list. That most of the words which are reacted to at a slower pace than average belong to the lookalike category may indicate that even in an unprimed state, when both L1 and L2 are active, the form similarity may confuse and inhibit rather than facilitate reaction times.

Language	Category	Word	Letters
NOR	lookalike	KURV	4
NOR	lookalike	RATT	4
NOR	lookalike	SKAM*	4
NOR	unrelated	TERMOS	6
NOR	unrelated	SIRKEL	6
ENG	lookalike	FABRIC	6
ENG	lookalike	CREEK	5
ENG	lookalike	CURVE	5
ENG	lookalike	SCAM*	4
ENG	unrelated	STAMP	5
ENG	unrelated	PIGEON	6
ENG	translation	FORK	4

Table 4.3: *Baseline* Median over SD, by category and letter number

Language	Category	Word	Letters
NOR	translation	HUND	4
NOR	translation	GUTT	4
NOR	cognate	FISK	4
NOR	cognate	DØR	3
NOR	cognate	PAPIR	5
NOR	cognate	FOT	3
ENG	translation	PIG	3
ENG	translation	DOG	3
ENG	translation	BOY	3
ENG	cognate	CUP	3
ENG	cognate	FISH	4
ENG	cognate	DOOR	4
ENG	cognate	FOOT	4

Table 4.4: *Baseline* Median under SD, by category and letter number

Median under sd (faster RT):

The general tenancy of the faster words is that these include few letters, and belong to cognates and translations. The results may be aided by the repetition and thus indicate an even higher effect for meaning relation. The cognate *paper* stands out in the -sd group, as it is the only word with a 5 letters, however, paper was one of the words which were assumed to be part of the outliers. This assumption was mainly due to the large number and high-frequent translations. Paper can be translated into Norwegian to mean:

- a sheet of paper
- cardboard
- newspaper
- magazine
- assignment

The indication that the high-frequency (and large list of translations in the case of *paper*) facilitate reaction time, would indicate that the translations of which were not matched for in the unrelated and lookalike categories could have influenced reaction times. The fact that there are many outliers in the +SD that belong to the unrelated and lookalike category indicate that the frequencies of their translations are not high enough to influence reaction time in a positive direction.

The Welch Two Sample t-test of the words reacted faster than (-SD) and the words reacted to slower than (+SD) shows a t-value of 4.1, degree of freedom 19,9 and a p-value of < 0,001. There is a *** significance between the two conditions over and under. This suggests that there is a highly significant difference between the number of letters within these categories. This difference was not accounted for in the first four experiments. The correction for the lexical reaction time may therefor adjust the priming effects found in the first four experiment.

4.2.4 Lexical reaction time

In the first experiments the variation could be explained by both lexical reaction time and priming effects. By using the lexical reaction time variation that was found in the baseline experiments as a standard proxy for normal lexical reaction time, made it possible to isolate the priming effects. In the datasets here, the identified lexical reaction time variation was subtracted from the first experiments, hence the remaining variation can be contributed to the priming effects. Effects for word length and frequency as well as standard lexical reaction times should thus be accounted for by the lexical reaction time correction, leaving a cleaner priming effect.

[3] skam and scam are the only two words in the stimuli which are not concrete nouns

Corrected Experiment 1 - Norwegian Target

Experiment 1 showed a main effect of meaning with a 42.2ms (**) decrease in reaction times for meaning related words. Form gave a 24.9 ms decrease in reaction time, however this was not significant. When correcting for the lexical reaction times found in the baseline experiments, neither meaning, form or their interaction showed a significant effect.

Norwegian target	Intercept	Meaning	Form
Before Correction	633,9	-44.2 (**)	-24.9
After Correction	610,28	-3.0	-13.16

Table 4.5: *Baseline* Mean reaction time before and after correction for Experiment 1

This suggests that for the L2-L1 direction, that most of the variation can be contributed to lexical reaction time. The interesting finding here is that the meaning effect almost completely disappears, suggesting that a much of this effect found before correction can be contributed to the words and the lower number of letters it the meaning-related categories. Although the form effect was non-significant before the correction and still remains non-significant after correction, it is wort noticing that the priming effect for form still remains at -13.16ms, whereas meaning priming only reduces reaction time by 3ms.

Corrected Experiment 2 - English target

Experiment 2 showed a three star significant effect for meaning (-45.5ms) but only a marginal effect for form (-2ms). Analyzing the experiment when corrected for the lexical reaction times, a significant effect of meaning is found with a remaining 20 ms decrease in reaction times, even after the effect of lexical reaction times are taken out. The -20ms effect for meaning is significant with a p-value < 0.05 *. The effects of form and interaction are non-significant for the English target experiment.

English target	Intercept	Meaning	Form
Before Correction	651.5	-45.5 (***)	-2.0
After Correction	643.9	-20.13 (*)	-7.6

Table 4.6: *Baseline* Mean reaction time before and after correction Experiment 2

This suggest that the meaning effect is stronger for the L1-L2 direction than for the L2-L1 direction. Indicating that meaning overlap increases activation of the first language, whereas form overlap only slightly aides the processing of an orthographically related word in L1.

Corrected Experiment 4 - mixed model

The observed reaction times from the baseline experiments generated an expected reaction time for each of the words used in Experiments 1-4. Here as well the Lexical reaction time for each word can be separated from the priming effect by using correction from the baseline experiments. Before the correction an effect of direction was found significant (*) and the effect of interaction between meaning and direction was found to be significant (*). There was also a lager priming effect for the strongest language (NOR) in the mixed mode (Experiment 4). After correction, an evaluation of the mixed language experiment 4 indicated that there is a significant main effect of meaning (-25,7 ***).

Mixed target	Intercept	Meaning	Form
Before Correction	677.7	-65.4 (***)	-10.7
After Correction	653	-25.7 (***)	-3.9
Norwegian target	Intercept	Meaning	Form
Before Correction	690.8	-73.9	
After Correction	683	-43.5	-5.8
English target	Intercept	Meaning	Form
Before Correction	657.7	-42.2	
After Correction	638	-6.3	-2

Table 4.7: *Baseline* Mean reaction time before and after correction Experiment 4

This suggests that although a large amount of the effects found before the correction are no longer present, meaning continues to be a highly significant priming effect in the mixed mode. When looking at the individual language directions this effect is no longer significant after the correction, however the priming effect for meaning continues to indicate a reversed effect than found in experiments 1 and 2. Where the L2-L1 direction in experiment 1 was almost non-existent (-3ms), in the mixed model a priming effect of -43.5ms remained. The meaning effect for L2-L1 direction in experiment 2 showed a significant -20.13ms reduction in reaction times for meaning related words, the same language direction in the mixed model showed only a -6.3ms reduction. These results point towards a difference in activation of languages across the tasks (single language vs multiple language lexical decision tasks).

Interaction effect of language direction and meaning before correction:

Figure 4.9 above shows the interaction effects of English and Norwegian across the + meaning (yes) and - meaning (no) categories. The interaction effect indicates that the mean reaction time for Norwegian in the mixed model experiment are much faster when the English prime was related to the Norwegian target through meaning (cognates and translations). When the English target was related to the Norwegian prime by meaning, a drop in reaction time occurred, however the drop in mean reaction times was not as large nor did it drop to the same level as for the Norwegian targets. For the orthographically related targets, English targets seem to have an advantage over Norwegian targets, suggesting that the influence of form is larger for English primed by Norwegian than the reverse.

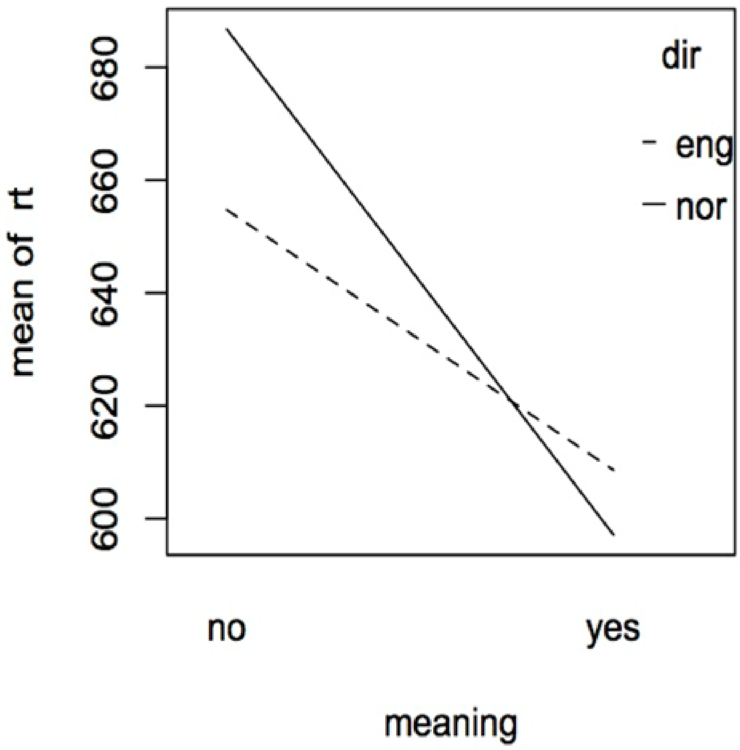

Figure 4.9: *Baseline* Interaction of language and meaning for Experiment 4 before correction

Corrected interaction effect of language and meaning:

Figure 4.10: *Baseline* Interaction of language and meaning for Experiment 4 after correction

After correcting for the lexical reaction times, the same tendencies were found, however, the mean reaction time for the - meaning conditions for the English target set drop from about 660ms to 640ms, whereas the Norwegian targets continue to have a mean reaction time of about 680 before and after correction. When the prime and targets are related by meaning both English target and Norwegian target pairs dorp to a mean of about 630ms.

4.2.5 Repetition effects

After designing the 3 experimental conditions of the baseline experiments, it was possible to investigate whether or not a repetition effect could be found. This was possible since all words were repeated once for each of the three baseline blocks. Baseline 1 includes only Norwegian targets, Baseline 2 includes only English targets and Baseline 3 includes all Norwegian and all English target words. All participants in the baseline experiments participated in all 3 baseline experiments, where each participant had a short break between each baseline block.

Repetition effect	Intercept	Position 2	Position 3
	602.5	-13.6	-48.4

Table 4.8: *Baseline* Repetition effects per position

The Linerar mixed model fit by REML confirms a repetition effect, as the second position experiments shows a decrease in reaction times by 13.6 seconds and the third experiment shows a further 48.4 ms decrease in reaction time. An anova test confirms that the repetition effect is highly significant $p < 0.001$ ***.

4.2.6 Instruction: Single language vs Multiple languages

It was also possible to study if the complexity of the task slowed down the reaction time for the participants. The results show that the mixed block is 20 ms slower than the single language blocks, indicating that the complexity of the task affects the results, as can be seen in the table below. An anova test shows that the task specific influences are significant with a p-value < 0.001 ***.

MIXED TARGET	592.4
NOR TARGET	-21.7
ENG TARGET	-19.2

Table 4.9: *Baseline*Mode of instruction across

4.2.7 Summary Experiment 1-4 corrected by lexical reaction time

Figure 4.11 shows the results of experiment 1-4, when corrected for lexical reaction times. The meaning effects found in Experiment 1 before correction (-44.2ms, ***) have almost

Experiment	Intercept	Meaning	Form	Direction
1 16 Subjects 611 Observations	610ms	-2.6 ms	-12.8ms	L2-L1nor
2 19 Subjects 767 Observations	645ms	-21.7ms *	-7.4ms	L1-L2eng
3 21 Subjects 750 Observations	675ms	-30.5ms *	-1.8ms	L3-L2eng (2nd lang)
4 21 Subjects 740 Observations	653ms	-25.7ms ***	-3.9ms	19.1ms
1a	683ms	-43.5ms ***	-5.8ms	L2-L1nor
1b	638ms	-6.3ms	-2ms	L1-L2eng

Figure 4.11: *Experiment 1-4* Summary corrected for lexical reaction time

completely disappeared and are reduced form a highly significant to a non-significant effect for meaning (-2.6ms). One possible explanation could be that a large part of the results in figure 4.5 are due to lexical reaction time differences, rather than priming effects.

Significant meaning effect were found in experiment 2,3 and 4, even after correction. Experiment 2 show that words primed by meaning (cognates and translations) gave a 21.7ms (*) lower mean reaction time. This result was repeated in experiment 3, where the meaning effect was 30.5ms (*) after correction.

In experiment 4, meaning effect was also found, and here it was more significant with a 25.7ms (***) faster mean reaction time. Interestingly this effect was found to be highly significant with $p<0.001$. These findings suggest that meaning priming leads to faster word processing.

Similar to the result described earlier in figure 4.5, an effect for meaning can still be detected after the correction for lexical reaction time as indicated in 4.11. The meaning priming effect in direction L2-L1 for experiment 4 (-43.5ms) and the lesser meaning priming effect for L1-L2 direction (-6.3ms). As the lexical reaction time correction has reduced the effect, but not changed the result, the same explanation may be given. The possible explanation that the reduced reaction time for the L2-L1 direction was that the dominant language was highly activated. This could result in reduced reaction times when the prime connects to the activated L1 through a meaning relation.

4.3 Experiments 5-8

4.3.1 Mixed language Experiments with counterbalanced Baseline

The purpose of these experiments were to further investigate the findings in experiment 4, within a more controlled setting. Experiment 4 revealed interesting results based on a mixed model, however only half of the word list was analyzed in each direction. Hence it would be interesting to investigate all words in both directions to see if these provided comparable findings. Another potential issue with the previous experiments were the fact that lexical reaction time was corrected by using results from another set of participants. This might be a inaccurate way of correcting for lexical reaction times since it is likely that participants have individual reaction times in accordance with their language proficiency levels. These may not match between groups, and this may not be appropriate to use as a proxy for lexical reaction time. To mitigate this problem a within subject baseline was included in experiment 5-8.

The experiments 5-8 are mixed language experiments with a counterbalanced baseline. The individual baseline ensures that the language proficiency of the participants are equal for both the baseline and experimental block. The switching of the target and prime pairs between experiments ensures that reaction time measurements are equal for both directions across all categories.

Experiments set-up

All four experiments recruited 12 participants each, drawn from the student population at the University of Bergen, giving a total of 48 participants across all experiments (5-8). Participants were between the ages of 18 and 47? and identified Norwegian as their native/primary language.

Experiment 5: Baseline + Experiment (odd Nor-Eng, even Eng-Nor)

Participants 12 participants took part in Experiment 5. Participants were between the ages of 20 and 27, (mean age of 24.083), and classified Norwegian as their native/primary language. All participants were students and participated of their own free will, without any compensation. Self-evaluation of their reading skills on a scale form 1-10 produce a mean of 9.33 for Norwegian (ranging from 8-10) and 8.5 English (ranging from 7-10).

Experiment 6: Experiment (odd Nor-Eng, even Eng-Nor) + Baseline

Participants 12 participants took part in Experiment 6. Ages ranged from 20-27 (mean age 22.66). All participants indicated Norwegian as their native/primary language. Participation was voluntary, without any compensation. Self-evaluation of their reading skulls on a scale form 1-10 produced a mean of 9.416 for Norwegian (ranging from 7-10) and a mean of 8.5 for English (ranging from 7-10).

***Experiment 7*:** Baseline + Experiment (odd Eng-Nor, even Nor-Eng) *participants* 12 participants took part in Experiment 7. Participant ages range from 20 -27 with a mean age of 23.5. All participants indicated Norwegian as their native/primary language and self-evaluated their reading skills, mean 9.166 for Norwegian (ranging from 7-10) and mean 7.66 for English (ranging from 6 - 10).

***Experiment 8*:** Experiment (odd Eng-Nor, even Nor-Eng) + Baseline

participants 12 participants took part in Experiment 8. Participant ages range from 18 to 47, with a mean age of 27.2 across the experiment. All indicated Norwegian as their native/primary language and self-evaluated their reading skills on a scale form 1-10. Norwegian gives a mean of 9.08 (ranging from 7 to 10) and a mean of 7.2 for English (ranging from 5-10).

4.3.2 Results of Experiments 5-8

In this section we have analyzed all the results from experiment 5-8 together. This is due to two reasons: firstly it provided a full picture of reaction times for all word pairs across both language directions and secondly, by counterbalancing the baseline it was necessary to analyze the response times together in order to cancel out the repetition effect. In the first chart we see a boxplot of the mean reaction times in each condition before correction for lexical reaction times.

All results are evaluated by a mixed effects model implemented in R-package LmerTest. Each model is then evaluated using an anova, and appropriate degrees of freedom are approximated by satterwhite' algorithms Winter (2013).

Reaction time by condition

Figure 4.12 shows reaction time by word category. The mean reaction times for each category indicate that meaning related word pairs create faster reaction times. This is in line with the earlier findings, which indicate that there is a strong main effect for meaning. Form created a small reaction time effect -14.3ms in the uncorrected data set, whereas mean created a reaction time effect -51.9ms in comparison. These effects can be seen in the table above, where cognates (+form and +meaning) are faster than translates (-form and +meaning). The -meaning categories are clearly slower, although lookalikes (+form and -meaning) are slightly faster than the unrelated category (-form and -meaning). Anova type III analysis shows a highly significant meaning effect $F(1, 59.26)=46.97$ $p < 4.689e-09$ (***), whereas form only approaches significance $F(1, 57.68)=3.9$ $p < 0.05$.

Corrected reaction time by condition

When correcting for lexical reaction times from the within subject baseline data, as figure 4.13 shows, a lot of the variation can be accounted for by lexical reaction time.

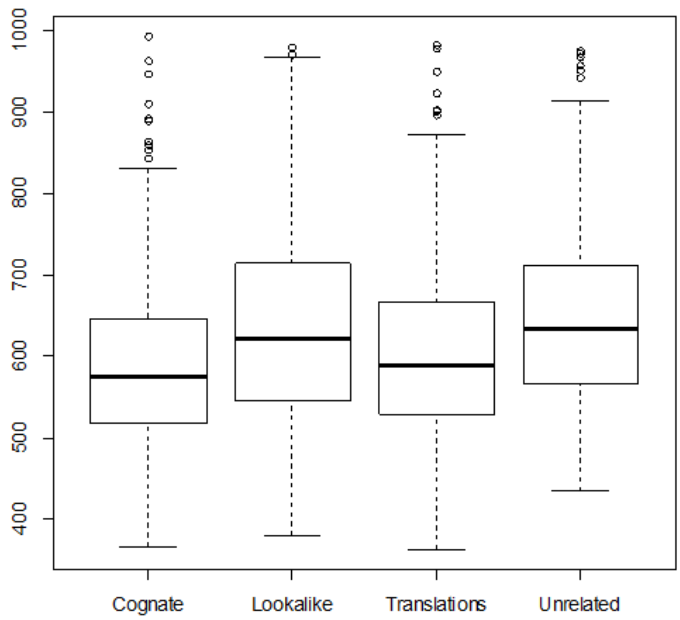

Figure 4.12: *Experiment 5-8* Reaction time across conditions before correction

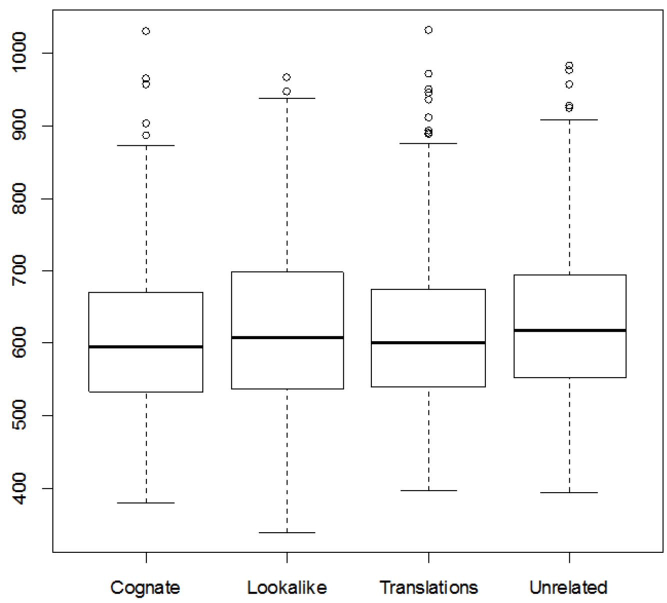

Figure 4.13: *Experiment 5-8* reaction time across conditions after correction

This would indicate that a lot of the variation across categories is not only due to meaning and form influences, but largely due to variation in lexical reaction times. When accounting for the lexical reaction time effects, a clearer effect of priming can be seen. Although the effects are smaller, meaning continues to improve mean reaction time by -32.4ms. Form reduces mean reaction times by 7.8ms. Indicating, as seen in the table above, that the mean reaction time for cognates is 7.8ms faster than the mean reaction time for translations. The gap between the mean reaction time for cognates (+ meaning and +form) and the mean reaction time for lookalikes (- meaning and + form) is thus 32.4ms. Anova type III analysis shows a significant meaning effect $F(1, 62.74)=5.9$ $p < 0.017$ (*), however form did not prove to be significant $F(1, 58.59)=1.8$ $p < 0.18$.

4.3.3 Main Effects

Meaning Effect

The main effect of meaning before correcting for lexical reaction times is highly significant $p < 0.001$ (**). When accounting for the lexical reaction time the effect prevails, $p < 0.027$ (*) although it is less significant after correction the results indicate that the priming effect is significant.

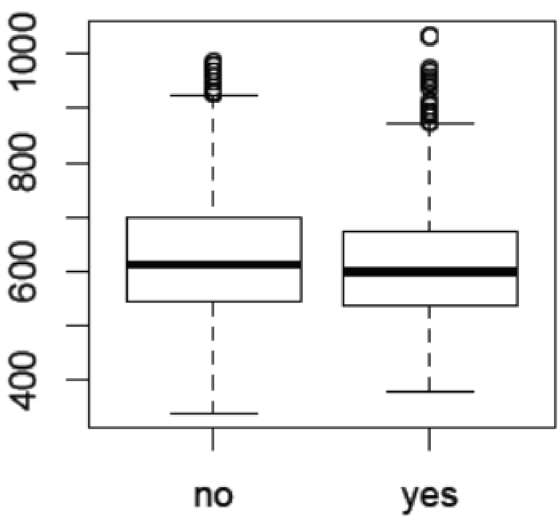

Figure 4.14: *Experiment 5-8* Main effect for meaning after correction

Figure 4.14 shows reaction time by meaning (yes= cognates and translations and no = lookalikes and unrelated) after correction. The mean differences may be small, 32ms advantage for the meaning related words, the anova type III shows that the main effect for meaning is significant $F(1, 62.74)=5.9$ $p < 0.017$.

Form Effect

The main effect for form, before correction for lexical reaction time approached significant levels, $p < 0.05$. The main effect of form after taking out the lexical reaction times, $p < 0.18$, is non-significant.

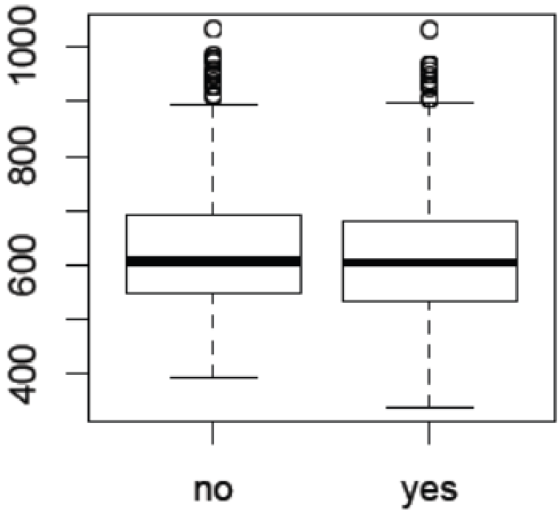

Figure 4.15: *Experiment 5-8* Main effect for form after correction

Figure 4.15 shows the corrected reaction times by form (yes = lookalikes and cognates and no = translations and unrelated). The mean advantage in reaction times between the conditions where form was present (yes) and where form similarities were absent was 7.8ms, although this was non-significant, this reduction in reaction times is a clear priming effect.

Language Direction

Figure 4.16 indicates that there is the reaction time effect for direction after correcting for lexical reaction time is about the same for L1-L2 and L2-L1 direction. A larger variation can be noticed for the L1-L2 direction.

Anova type III analysis showed a highly significant effect for direction before correction $F(1, 72.15)=12.96$ $p < 0.001$ (***). After correcting for lexical reaction time the same anova test on the corrected data set showed a non-significant effect $F(1, 80.24)=1.11$ $p < 0.29$. This would indicate that the effect for language direction is significant, although it does not seem to be due to priming.

Repetition Effect

One effect that was significant was the repetition effect. The ANOVA type III analysis showed $F(1, 48{,}86)=12{,}645$, $P<0.001$, ***, reaching the highest level of significance. This would indicate that repetition of words reduces reaction time. Although the repetition effect

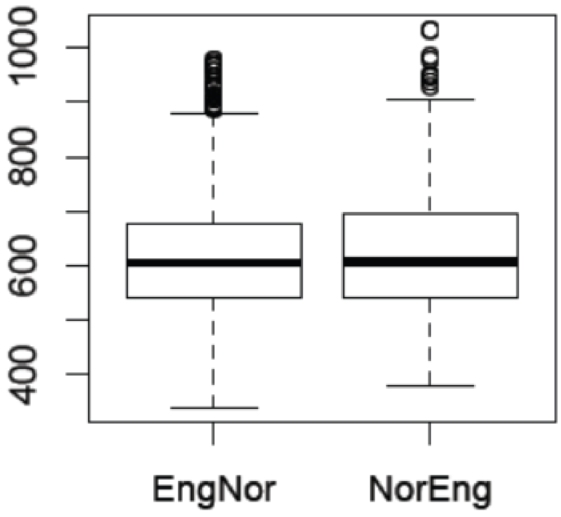

Figure 4.16: *Experiment 5-8* Main effect for direction after correction

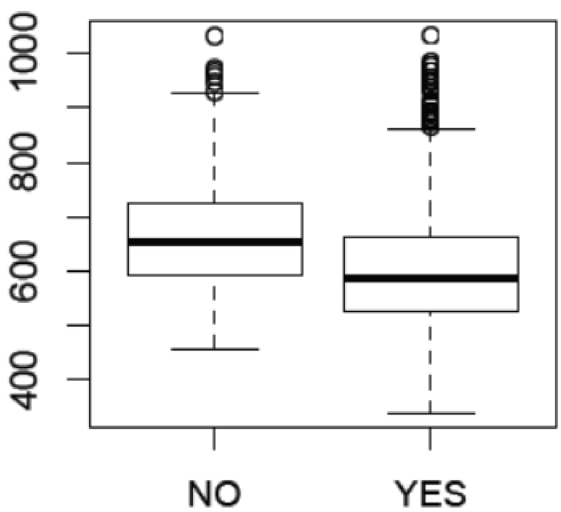

Figure 4.17: *Experiment 5-8* Main effect for repetition after correction

are highly significant, one should take into account that they only include the repeated target conditions. Words that were repeated as a prime were tagged as *repeated as prime*, these were not included in the analysis. This was done in order to avoid skewed results as the prime words are visible for only 100ms whereas the target words are visible for 1000ms.It could be interesting to look into the difference between the repeated target conditions and the instances where the prime is repeated to see if there is a difference in effect of repetition with regards to the time the word was visible. However this has not been done in this study.

4.3.4 Interaction effects

When analyzing the results from the experiments 5-8 it became evident that there were several interaction effects.

Form and Repeated

When the form was similar and not repeated, reaction time was higher then when form was not similar and the word not repeated. Once repeated, this effect changes, and words with similar form have a faster reaction time than words with no similar form.

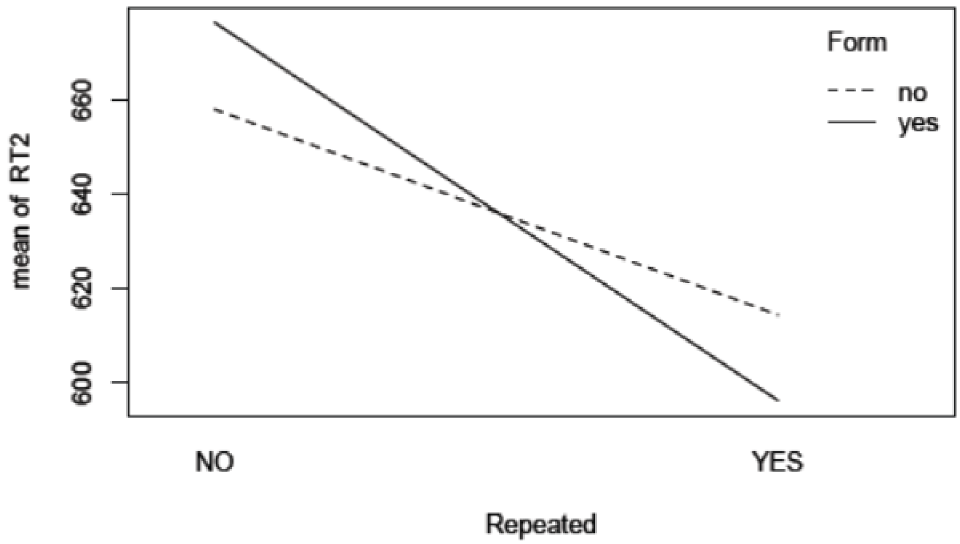

Figure 4.18: *Experiment 5-8* Interaction effect for repetition and form

The ANOVA conducted on the interaction of *form* and *repeated* revealed a significant interaction effect F(1, 856,12)=9,81, $p < 0.002$**. Indicating, as shown in the graph above, that the form similarity (form = yes) reduce the reaction time drastically when repeated, whereas the same is not true for the instances where there is no form similarity (form = no). This effect is similar to the same effect found before correction ($p < 0.0087$***), indicating that this effect is mainly due to priming, not however to lexical reaction time effects.

Meaning and Repeated

One of the smaller interaction effects that was found was between meaning and repetition. Words with no meaning had relative higher reaction effect when not repeated, then when they had been repeated.

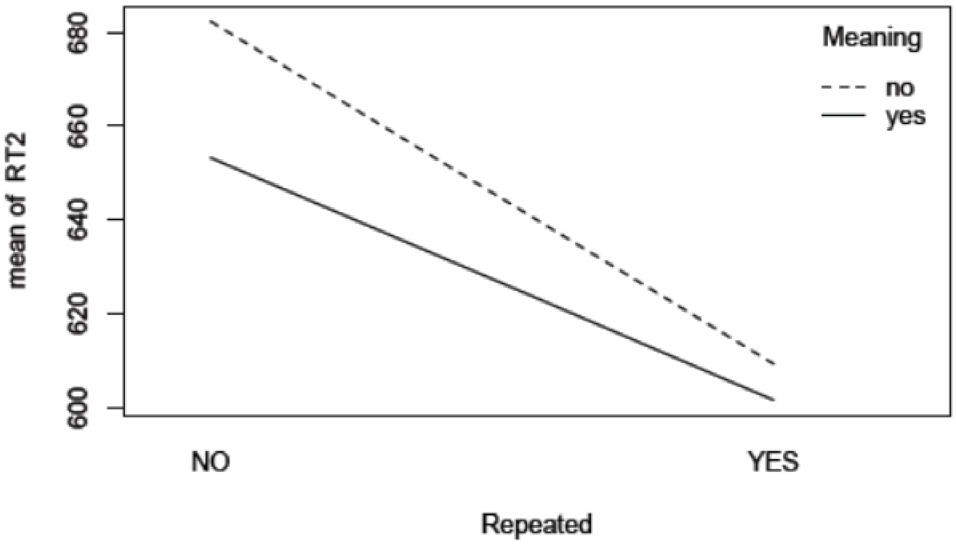

Figure 4.19: *Experiment 5-8* Interaction effect for repetition and meaning

The ANOVA conducted on the interaction of *meaning* and *repeated* revealed a significant effect of interaction $F(1, 856,27)=4,12$, $p < 0.05$ *. In the instances where there was a meaning relation (meaning = yes) between the prime and target, the overall reaction times are shorter than they are in the instances where there was no meaning relation (meaning = no). When both repeated, the words without meaning relation are reacted to almost as fast as those with meaning relation, indicating that the repetition effect is stronger for the words without meaning relations than those with.

Direction and Repeated

The interaction of the language direction of the word pairs Norwegian prime and English target (NorEng) and Norwegian targets primed by English (EngNor) and repetition of the target as shown in the graph below indicate that when a word is repeated the drop in reaction times are greater for English target words than for Norwegian targets.

As seen in the graph, when there was no repetition, the reaction time was higher for English targets, once the word had been repeated, the reaction time for english targets fell to the similar levels as the Norwegian repeated targets. Hence it took longer for the participants to respond to a English target at the first time. The ANOVA conducted on the interaction effects of language direction and repeated did not however reach significant levels, indicating

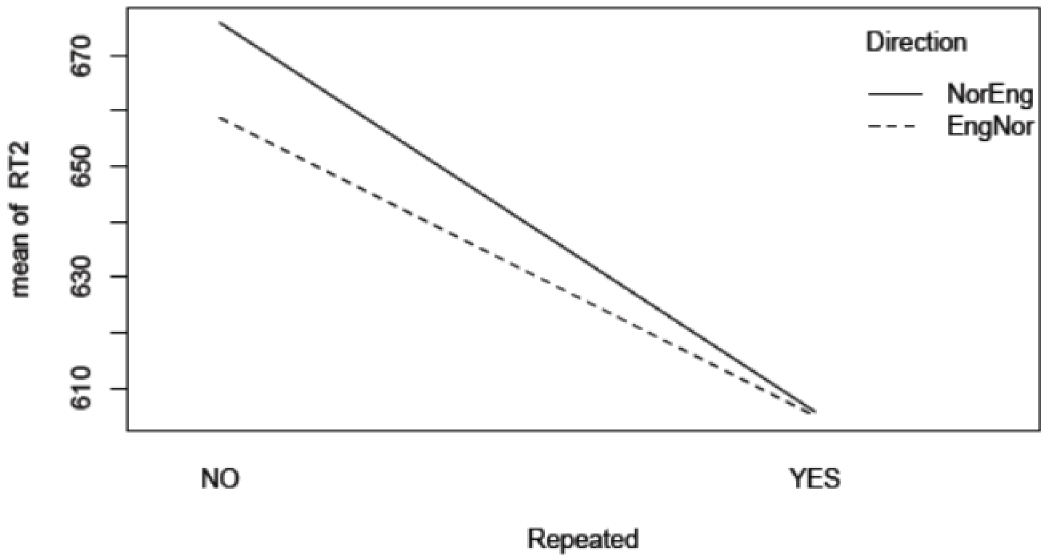

Figure 4.20: *Experiment 5-8* Interaction effect repetition and direction

that these results are highly uncertain, and should either be disregarded or investigated further in future studies.

Other non-significant interaction effects was also found for direction and meaning, and direction and form.

4.3.5 Summary

The summary table below shows that the effects of form and meaning in experiments 5-8 are consistent before and after correction. The expected difference is that effects are smaller after correction than before. Figure 4.21 shows the same meaning advantage as were found in the previous experiment. Form similarities only improve reaction times slightly, and are non-significant both before (14.3ms) and after correction (-7.8ms). Whereas meaning is highly significant before correction (-51.9ms) and remains significant even after correction (-32.4ms). Indication in line with the previous findings, meaning relations between prime and target pairs facilitate reaction time responses significantly.

Experiment 5-8	intercept	Meaning	Form	Direction
Before correction	653.1	-51.9 **	-14.3	Mixed
After correction	647.7	-32.4 *	-7.8	Mixed

Figure 4.21: *Experiment 5-8* Summary

Chapter 5

Discussion

The initial aim of the present study was to investigate how two aspects, form and meaning, of written words affect a bilingual's recognition process. The same stimuli was tested in both single language target experiments and mixed language target experiments giving an overall picture of the process of word recognition in all directions. The experimental design was with marginal variation the same across all experiments giving a well controlled outcome such that all experiments could be compared to each other and thus giving a good overview of the effects of meaning and form in the open priming paradigm. The following sections will give a short summary of previous findings with regards to interlingual homographs and cognates and a short discussion of how the findings of this study may fit into the previous research patterns. Priming effects and the issue of lexical reaction times will be discussed as well as issues with the study and how these were dealt with, followed by suggestions for further research and ending with a short conclusion of the findings.

5.1 Findings

5.1.1 Orthographic aspects of representation in interlingual homographs and cognates

Studies have shown that homographic cognates such as *film, hotel and taxi* are consistently processed faster in L2 lexical decision tasks (Lemhöfer and Dijkstra, 2004; Caramazza and Brones, 1979; Dijkstra et al., 1998). The cognate effect is less robust for L1 lexical decision tasks as are the findings for non-identical cognates (Cristoffanini et al., 1986; Font, 2001; Van Hell and Dijkstra, 2002). In the study by Caramazza and Brones (1979) a cognate effect was found for the L2 tasks (English lexical decision), whereas no difference in reaction times were found between cognates and non-cognates for the L1 tasks (Spanish lexical decision), suggesting that the cognate effect is present only for L2. However, a cognate effect was found in a lexical decision tasks where the L1 targets were cognates for either L2 or L3 by Van Hell and Dijkstra (2002) as well as Lemhöfer and Dijkstra (2004). The study by

Lemhöfer and Dijkstra (2004) also indicates that orthographically identical cognates were reacted to faster than both L1 and L2 control words, indicating that the cognate effect is strong across languages (Lemhöfer and Dijkstra, 2004).

The findings of this study show that there is a greater advantage for meaning related words for the L2 lexical decision task (-21.7ms) for experiment 2 (after correction), than for L1 lexical decision tasks (-2.6ms). Which are in line with the findings by Cristoffanini et al. (1986); Font (2001) and Van Hell and Dijkstra (2002). A difference in effect was not however found between the non-identical cognates and the translations pairs in the current study. That the effects of meaning were less pronounced in the L1 lexical decision task may be due to the high frequency of the words and the overall mean reaction time in experiment 1 being near equal to the overall reaction time for the baseline (lexical reaction time). Within the mixed mode, the largest meaning effects were found -25.7ms for experiment 4 and -32.4ms for experiments 5-8, indicating that meaning relations effect the reaction time at a greater rate in the mixed language lexical decision tasks. One explanation for the larger effect in the mixed mode may be that both languages are activated to a greater extend, as participants are instructed to look for both Norwegian and English words, rather than only English or only Norwegian. However, the difference in effect is small between the different language conditions and non-significant. The difference in effect could thus be explained by other variables.

Interlingual homographs such as *fire* which means *four* in Norwegian, usually do not exhibit facilitatory effects (Lemhöfer and Dijkstra, 2004). The study Dijkstra et al. (1998) found no difference in response times for interlingual homographs (Dutch-English) and matched controls, in a single language lexical decision task when all *no* answers were non-words across languages. When a subset of the words requiring a *no* answer were words in the non-target language, the response times for interlingual homographs were longer (Dijkstra et al., 1998). De Groot et al. (2000) found that interlingual homographs were more difficult to process than their matched controls, within a single-language lexical decision task, although only when their less frequent reading had to be selected. Difference in results seem to suggest that the effects of interlingual homographs depend on several factors, such as frequency characteristics of the words, the task requirements and the mono- or bilingual composition of the stimulus list. The current study did not find facilitatory effects for orthographic overlap between languages across the set of experiments, these results are in line with the findings by De Groot et al. (2000).

5.1.2 Single or separate and selective or non-selective lexical access

Perhaps the most enduring questions in psycholinguistic studies center around the language stores and how these are accessed. The language store debate is divided by a single store system and a separate store system. The single store system assumes that a bilinguals language's are stored in a common system that governs memory representation and processing devoted to all languages in the multilingual mind. The separate system assumes that there is one language specific system governing memory representations and processing for each of a bilingual's languages (Kroll et al., 2005, p. 531). Both the separate system and the single system hypotheses can be supported by life experience. That bilinguals appear to be able to function in life without frequent or random intrusions of their knowledge of other languages point towards a separate store hypothesis, whereas the fact that bilinguals can code switch when speaking to other bilinguals suggests that two languages may be activated simultaneously and thus argues for a common or shared language system (Kroll et al., 2005, p.531).

The first models which tried to evaluate the structure of languages such as the three systems proposed by Weinreich (1953) failed to take into account procedural effects and distinctions among levels of representation. The revised hierarchical model, although accounting for levels of acquisition faces the same problematic as the word-association and the concept mediation theories of language organization. These first models assume that the way in which languages are represented need to be the same for orthography, syntax, phonology and semantics (Kroll et al., 2005). The question of whether or not a bilinguals languages are shared or separate may then be answered differently for different aspects of language representation.

Another issue concerns the language selective or non-selective view. Early research indicated that there may be a language input switch, which effectively enables one language and suppresses the other (Macnamara and Kushnir, 1971). The language selective access hypothesis assumes that a bilingual has two separate lexica which are accessed dependent on the language input, the language non-selective hypothesis assumes that the bilingual's languages are simultaneously activated during the word recognition process. Early research often assumed that if the two language of a bilingual are stored in an independent memory system, a selective view of language processing was often adopted (Kroll et al., 2005). However, Van Heuven et al. (1998) pointed out that it is possible to have a shared memory representation with a parallel and non-selective access (Kroll et al., 2005, p.532).

Arguing for a more task-specific model the shift occurred form the generalized models to the interactive models, focusing on the different processes involved in the interaction of two (or more) languages. The question of separate versus common system endures, although the focus of attention shifted.

In a separate lexicon, only neighbors of the same language are assumed to be activated. On the other hand the common system assumes that the process of retrieving lexical information is language independent, such that the input is in competition with neighbors from both of the bilingual's languages. The robust meaning effects found in this study, across all experiments, indicate that the process of lexical retrieval is language independent, as the same meaning facilitation results are present in all language directions within this study. The non-significant and very small form influences across the series of experiments of this study suggest that the orthographic neighborhood activation may not be as crucial to the process of word recognition, at least for very high frequent words. The difference in reaction times across word categories in the unprimed (baseline) study, suggests that the form similarities are non-significant in comparison with the meaning related effects. Given that the Norwegian word *papir* is consistently reacted to faster than other 5 letter words, it may be the case that the high frequent English translations exhibit facilitatory results. Thus supporting a non-selective access hypothesis.

The current study does to some extend support both the lexical non-selective hypothesis and the selective hypothesis. In accordance with Experiment 1 in the study by Dijkstra et al. (1998) a facilitatory effect (reduced reaction time) was found for cognates, suggesting a language non-selective access. The interlingual homographs did however not differ significantly from the baseline, suggesting that the inhibitory and facilitatory relationship between the semantic and form representation of the interlingual homograph points towards a language-selective access. However, the main findings in this study suggest that meaning is the main facilitatory component in cross-linguistic lexical decision tasks, which strongly indicates a language non-selective access.

5.1.3 Models of language processing

The interactive activation models assumes that there is an interaction of both bottom-up and top-down processes that drive word recognition. The bottom-up process is driven by visual features, indicating that if the letter string in a given word is familiar, each of the visual features in that letter string will aid the recognition process. This seems to be in line with experiment 1, where a relatively large (although non-significant) effect for form is found (-24.9ms before correction). After correcting for lexical reaction time visual features are even less (-12.8). The L2-L1 priming direction of experiment 1 exhibits the largest influence of visual features on reaction time, indicating that the cross-linguistic word recognition process exhibits facilitatory effects more heavily when a less dominant language is the first visual input. That form does not significantly affect word recognition in any of the experiments indicates that the bottom-up process may not carry as much weight in the word recognition process as assumed by the interactive activation model. However, this model was designed as a monolingual model of word processing and thus the effects of visual input may vary for monolingual and bilingual speakers.

The BIA model assumes the same structure as found in the interactive activation model, however assuming that the bottom-up process includes a non-selective language activation. This would suggest that the languages of a bilingual are activated simultaneously in the initial processes of word recognition. Szubko-Sitarek (2015) aruges that if access is language selective, the fact that words are cognates or have many neighbors in another language should have no effect on reaction times. If access is non-selective, candidates from both languages will present themselves and this competition will again lead to longer reaction times (Szubko-Sitarek, 2015, p.86).

Lemhöfer and Dijkstra (2004) found in the generalized experiment (4) that orthography alone (interlingual homographs) did not facilitate response times. The addition of semantic overlap (cognates) did facilitate the word recognition process. This is in line with the results found across all experiments in this study. However, it can be argue that one of the reasons for the cognate effect may be that the cognate share a single orthographic representation. As this study included only non-identical cognates, this suggests that the effect of cannot be due to a cumulative frequency, but rather involves semantic feedback (Lemhöfer and Dijkstra, 2004, p.546). This would suggest that cognates have two separate orthographic representations and that the shared meaning is the facilitatory factor.

Interlingual homographs are assumed, by the BIA+ model, to represent two different orthographic representations, where each is connected to its own semantic representation. The small effects for form similarities suggests that the orthographic overlap between the non-identical interlingual homographs in this study do not aid the word recognition process significantly. That the translations pairs (mismatched orthography) resulted in a cognate-like response time, suggests that meaning is the main drive in reducing reaction times across the different conditions within these lexical decision tasks.

5.1.4 Masked vs unmasked priming

Forster (2015) argues that the a purer form of priming can be found within a masked priming experiment, than an open priming experiment. However, it may be possible that the masked priming paradigm and the unmasked measure different stages of lexical access. Where Forster et al. (1987) found form priming with graphimically similar prime-target pairs in the masked priming design. The results of the current open priming study indicate that the form overlap is only slightly speeding up the reaction times. The main differences between these two studies are the stimulus onset asynchronies, (60ms) in the study by Forster et al. (1987) and 100ms in the current study. The differences in findings, form priming vs no form priming, may suggest that if the prime is visible for longer than 60ms the meaning corresponding with the letter string is activated. If the process of recognition stats with the form processing and stops when the corresponding meaning is retrieved, it seems to reason then that the meaning is more activated at the end of the process, such that a target word which would be presented after the meaning is retrieved would overpower the form activation. Thus for longer prime exposure a larger effect for meaning would be found and the form effect would be small, when the prime exposure is shorter as in the study by Forster et al. (1987).

5.1.5 Meaning advantage

The present study shows a clear main effect of meaning across the single target language experiments as well as the mixed language experiments. Although variation between L2-L1 (experiment 1) and L1-L2 (experiment 2) can be observed, the main difference between the two language direction is the form influence. The orthographic overlap between non-identical interlingual homographs and the non-identical cognates facilitate reaction time effect only slightly in the L2-L1 condition, whereas no facilitatory effect for from likeness are found in the L1-L2 condition. Facilitatory effect for meaning were consistently strong, although not always significant. The BIA+ model assumes that the language representation of a second language are at a subjectively lower level of activation than those of the first language, this hypothesis is supported by the mean reaction times across Experiments 1 (L2-L1) and 2 (L1-L2), where the overall mean reaction time across categories is lower for the first language target experiment than for the second language target experiment. The mixed target language has higher mean reaction time than the L2 target language experiment, contributing to the verification of the task specific influence on reaction time.

5.1.6 Lexical reaction time

Within the first four experiments the category *unrelated (-meaning/-form)* was used as a baseline. Allowing for a comparison of the reaction times between the category where both meaning and form similarities were absent with the conditions where either both or one were present. Within all categories frequency was used as a proxy for lexical reaction time, such that all word pairs were matched within a confidence interval. As the frequencies of each of the words were reexamined after the first four experiments indicated that this way of estimating reaction times may not have been ideal.

Creating a separate baseline study to validate the findings of the first four experiments indicated that there may be lexical reaction time differences which should be accounted for. For experiments 5-8 some different scenarios were considered. A within-subject baseline was preferred, as it would give the best indication of the lexical reaction times for each participants. Although a separate baseline study with a set time frame between the baseline and the experiment may have been preferable, this was impossible within the time frame and without compensation for the participants, it would have been difficult to get each participant into the lab at set times. The alternative within-subject design was a counterbalanced design with a baseline either before or after the experiment, which was the design that was ultimately used in experiment 5-8.

The counterbalanced design ensures that the problems of variation between subjects (language fluency, task proficiency etc.) of the baseline study and the main experiment do not vary. The before and after conditions create the opportunity to take out repetition effect and thus finding a well matched baseline.

The baseline design that was used in experiments 5-8 provides a stable measurement of reaction times for each word which can be used to estimate frequency or closeness to mind in a more accurate way than the frequency estimations which were used to create the unrelated category. Evaluation of the unprimed states of the words showed that there was a difference in reaction times for meaning related words. This suggests that a counterbalanced baseline where the lexical reaction time can be measured for each word may be a better way of estimating the priming effect for lexical decision tasks as this takes out the uncertainty of frequency measurements across languages and accounts for the language proficiency of the participants. This allows for measurements of accurate priming effects across all conditions.

One potential problem with the counterbalanced models is that if the experiment is first the participant will most likely be aware of all words, however only half of the words will be in the target position. If the baseline experiment is first the participant will have seen all words, both target and prime of the following experiment. Such that for the experiment+baseline order participants will see 40 words which previously had been seen only for 100ms (as prime words) and 40 words which were previously seen as target words (1000ms). For the baseline+experiment order participants will have seen all 80 words as target words (1000ms). This may need further testing to see if there is a difference in reaction times for the two conditions in order to conclude that this counterbalanced design is effective. However, as most participants reported that they were able to see the prime, the exposure time for the prime words in the experiment+baseline order could arguably be enough to balance the design sufficiently. Experiments 5-8 should account for the difference, as they are not only counterbalanced for the baseline but also for the language direction of the experiment, such that each word is measured in all directions for all orders.

5.1.7 Meaning advantages for beginner-learners (L3-L1)

Experiment 3 aimed to investigate if there is evidence for meaning or form priming when beginner-learners are primed by their least dominant language, in this case Norwegian. All participants were dominant speakers of a language other than English and judged as advanced English speakers, similar to the Norwegian participants of the other experiments. The main motivation for this experiment was to investigate whether or not there would be any meaning priming for these naive learners, or if the form similarities between the unfamiliar Norwegian words would trigger faster response times for the orthographically similar English words.

Although faster response times were not expected for meaning related words within this group large priming effects were found for cognates (-54,8ms) and translations (-53,8ms). For the 21 subjects who participated and the 750 observations the LMER analysis showed an unexpected and highly significant effect for meaning priming (-50,6***).The strong meaning priming effect could indicate that meaning relations, both cognate and non-cognate, are established at a rather fast pace. The relatively high frequency of the words used, may have contributed to the results, as participants would have been likely to have encountered a lot of the words during their stay in Norway.

The lack of priming effects found through the LMER test for form (+7,5ms) within the beginner learner group suggests that there is an inhibitory effect for lookalikes, words which only share form similarities across languages (+2,2ms).

Even after correcting for LRT the main effect of meaning (-30,5ms after correction) continued to be significant ($p<0,05^*$). The form effects are non-significant both before and after correction (-1,8 after correction). However, experiment 3 was corrected for the LRT found in the baseline experiments. As the participants in the baseline studies are dominant Norwegian speakers, they are expected to respond faster to Norwegian words than the average participant in the beginner-learner experiment. It could therefore be argued that correcting for advanced speaker's lexical reaction times may not be ideal. Although the results for this experiment show that the significant effects before correction remain after correction. A within subject baseline would give a more accurate account of effects, however, the tendencies would predict that the effect for meaning would remain significant and the form effects non-significant.

The expectations of form priming were not met, as these seem to be rather more inhibitory than facilitatory. Although the overall reaction times for the beginner-learner group was higher than the reaction times for the other experiments, the meaning effect for this group was the overall largest. That the non-Norwegian speaking participants produced the same magnitude of priming effects as the native Norwegian speakers, was a surprising result. However, looking at the findings by Gullberg et al. (2010), a series behavioral and neuroimaging studies suggest that adults can identify segmental, phonotactic and lexical knowledge of an unknown and typologically distant language after only 7-14 minutes of exposure. That meaning relations should form rather rapidly across languages, when the learner is exposed to a new language at a daily basis over a longer period of time, may then not be uncommon.

5.1.8 Evaluation of the stimuli

A possible reason for why a difference was detected between + meaning categories (cognates and translations) and the - meaning categories (lookalikes and unrelated) may be that when a concept is activated it is closer to mind, such that if one of the words in a meaning-related word pair is activated, it is likely that the activation prevails, thus decreasing the response time for the meaning-related counterpart.

Finding unrelated pairs is objectively easier than finding translation pairs, as there are many more unrelated word pairs than related. However, for humans it is subjectively harder to find an unrelated word pair. Thus, it takes human subjects longer to find an unrelated word pair, than it does to find a translation of a word, making it subjectively harder to find an unrelated word pair. This indicated that translation pairs are to some extend closer to min which implies that such selected words will have faster reaction times even without priming Stremme and Johansson (2015).

Because of this influence it may seem to reason that any stimuli list may have unforeseen problems. The lexical reaction time (baseline) should however account for these differences, such that a priming effect can be subtracted from other potential influential factors.

5.2 Further Research

There are a number of unanswered questions that need attention. It would be interesting to see, if there is a difference between the reaction times of a separate baseline and an integrated baseline (using the same participants for both, not as with the separate baseline). In order to establish which practice is the best in future experiments. Another interesting aspect would be to see if the robust effect of meaning that was found across all of the experiments in this study would hold if the experiments were replicated in a masked priming paradigm. It would also be interesting to see if an open priming experiment with a stimulus onset asynchorny of about 50ms would yield a stronger effect for form priming. Additionally a better controlled L3-L2 experiment would be of interesting as the correction for this experiment may have influenced the results.

5.3 Conclusion

The findings of this study suggest that the meaning relations exhibit facilitatory effects, rather than the orthographic similarities. Both cognates and translations were consistently reacted to faster than lookalikes (interlingual homographs) and unrelated words across all experiments. A robust main effect of meaning across all variations of the experiment (even the baseline study) indicates that meaning relations are independent of language. This would in turn suggest that the word recognition process of familiar words is mainly dependent on the semantic activation, rather than form similarities. The variance in the unprimed baseline study suggests that the meaning is non-selectively accessed, as the +meaning categories even in the unprimed state were consistently outperforming the -meaning words within the stimuli list. Word lists made for the purpose of testing similar vs different words across languages may likely be subjected to bias, as it is subjectively harder for people to find different or unrelated word pairs than finding similar or related word pairs. However, taking the lexical reaction time into account, the facilitatory effects of word length, frequency etc, eliminate the influences of these factors when comparing them to their primed counterparts. That the meaning effect prevailed even after correcting for lexical reaction times, suggests that the main effect of meaning that was found in these experiments is indeed due to priming. The results of this study would suggest that there is a common conceptual store where the meaning bearing units are activated through language non-selective access. It seems that form similarities across languages are to some extend actively inhibited. Given that the visual features of words are linked to phonological codes, the inhibitory effect may be explained by the different articulatory processes involved in the pronunciation of each of the visual features. Assuming that when two words which belong to different languages are orthographically similar, these similarities may not be enough to facilitate response times if these are inhibited by phonologically dissimilar associations. In conclusion, the findings indicate that cross-language priming is driven by by top-down meaning bearing units, rather than bottom-up visual features.

Appendix A

Stimuli

The content of the following tables are the word pairs within each of the four categories that were used in the experiments. Each word is assigned a number such that the directionality of the word pairs in experiments 5-8 can be traced. The assigned number of the word is equal across all experiments.

Lookalikes			
1	TØY	41	TOY
2	FARMOR	42	FARMER
3	FABRIKK	43	FABRIC
4	KRIG	44	CREEK
5	KURV	45	CURVE
6	RATT	46	RATT
7	SKAM	47	SCAM
8	KOR	48	CORE
9	SJEF	49	CHEF
10	BUKSER	50	BOKSER

Table A.1: Lookalikes (- meaning, - form)

Unrelated			
11	ELG	51	CASTLE
12	NØTTER	52	ARROW
13	MÅNE	53	PRINTER
14	PUDDER	54	SKULL
15	TERMOS	55	STAMP
16	FLØYTE	56	PIGEON
17	SKJORTE	57	GHOST
18	KNIV	58	MUD
19	SIRKEL	59	BANANA
20	SVERD	60	ELEPHANT

Table A.2: Unrelated (- meaning, - form)

Translations			
21	FUGL	61	BIRD
22	BLYANT	62	PENCIL
23	TORSK	63	COD
24	BILLETT	64	TICKET
25	GAFFEL	65	FORK
26	GRIS	66	PIG
27	HUND	67	DOG
28	GUTT	68	BOY
29	FLASKE	69	BOTTLE
30	STOL	70	CHAIR

Table A.3: Translations (+ meaning, - form)

Cognates			
31	SUPPE	71	SOUP
32	KOPP	72	CUP
33	GRESS	73	GRASS
34	NESE	74	NOSE
35	FISK	75	FISH
36	DØR	76	DOOR
37	PAPIR	77	PAPER
38	RIS	78	RICE
39	BALLONG	79	BALLOON
40	FOT	80	FOOT

Table A.4: Cognates (+ meaning, + form)

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