A Cross-linguistic Form and Meaning Priming Study on Mandarin Chinese Multilingual Speakers

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Abstract

In four experiments, form and meaning priming effects in native speakers of Mandarin Chinese with English as their second and Norwegian as the third language were investigated with a series of lexical decision tasks. The form and meaning influences across languages were tested through four categories: cognates (+meaning, +form), false friends (-meaning, +form), translations (+meaning, -form) and unrelated (-meaning, -form). By using the same stimuli, experiments 1 and 2 examined the interaction between Chinese and Norwegian. The priming effect was confirmed for meaning-related word pairs, but only when primed by Chinese words. Neither meaning nor form effect was demonstrated when primed by Norwegian words. Adopting the same paradigm, experiments 3 and 4 investigated the influences of meaning and form on lexical reaction times between Chinese and English. Priming effects for cognates and translations were observed from both Chinese to English and the reverse direction, whereas form priming effect was only found when primed by English primes. Chinese nonwords were faster to decide than alphabetic language groups in all conditions. This is interesting since a word superiority effect predicts faster responses for words (Paap et al. 1982). It is possible that Chinese non-words may be decided without phonological encoding, which is necessary for lexical retrieval in alphabetic languages.

The results are in line with previous findings that lexical items in different languages are processed through semantic connections. Stronger facilitation in word recognition was found for meaning-related words than form-related words. Priming asymmetry was also observed that larger effects of priming from L1 to L3 (Chinese to Norwegian) than from L3 to L1, meaning advantage was found from both L1 to L2 (Chinese to English) and L2 to L1, only form priming effects were confirmed from L2 to L1 (English to Chinese), suggesting that proficiency might play a role in lexical access. As for discrimination of nonwords, fast and accurate decisions on Chinese

nonwords suggests that different routes or analytical skills might be involved in recognizing Chinese signs and the alphabetic string of letters. For Chinese, lemma can be activated through the combination of radicals or semantic radicals before phonological encoding.

Sammendrag

I fire eksperimenter ble priming-effekter i mandarin-kinesiske morsmål med engelsk som andrespråk og norsk som det tredjespråk ble undersøkt med en serie leksikale beslutningsoppgaver. Innflytelse av form og betydning på tvers av språk ble testet gjennom fire kategorier: kognater (+ betydning, + form), falske venner (-betydning, + form), oversettelser (+ betydning, -form) og ikke-relatert (-betydning, -form). Ved å bruke de samme stimuli, undersøkte eksperiment 1 og 2 samspillet mellom kinesisk og norsk, der primingseffekten ble bekreftet for meningsrelaterte ordpar bare når den ble grunnlagt av kinesiske ord. Verken betydning eller formeffekt ble påvist når de ble primet av norske ord. Ved å ta i bruk samme paradigme, undersøkte eksperimentene 3 og 4 påvirkningene av mening og form på leksikalske reaksjonstider mellom kinesisk og engelsk. Grunningseffekter for kognater og oversettelser ble observert fra både kinesisk til engelsk og motsatt retning, mens forming av primingeffekt bare ble funnet når grunnet av engelske primater. Kinesiske nonwords var raskere å bestemme enn alfabetiske språkgrupper under alle forhold. Dette er interessant da «the word superiority» forutsier at det bør være raskere å beslutte ord enn ikke-ord (Papp et al. 1982). Muligvis besluttes kinesiske ikke-ord uten at de blir fonologisk kodet, og i alfabetiske språk må orden kodes for å hentes fra leksikon, noe som kan ta lenger tid for ikke-ord.

Resultatene er i tråd med tidligere funn om at leksikale elementer på forskjellige språk blir behandlet gjennom semantiske forbindelser. Sterkere tilrettelegging i ordgjenkjenning ble funnet for meningsrelaterte ord enn formrelaterte ord. Assymetrisk priming ble også observert gjennom større effekter for grunning fra L1 til L3 (kinesisk til norsk) enn fra L3 til L1, noe som betyr at en fordel av samsvar i betydning ble funnet fra både L1 til L2 (kinesisk til engelsk) og L2 til L1, men effekter av priming av form

kun ble bekreftet fra L2 til L1 (engelsk til kinesisk), noe som tyder på at ferdigheter kan spille en rolle i leksikalsk adgang. Når det gjelder diskriminering av nonwords, antyder raske og nøyaktige beslutninger om kinesiske nonwords at forskjellige ruter eller analytiske ferdigheter kan være involvert i å gjenkjenne kinesiske tegn og den alfabetiske bokstaven. For kinesere kan lemma aktiveres gjennom kombinasjonen av radikaler eller semantiske radikaler før fonologisk koding blir avklart.

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Chapter 1 Introduction

With the globalization of the world, there is an increasing number of people who can speak more than one language. Some children are growing up in a bilingual setting. This gives us an opportunity to study bilingualism or multilingualism. The intuition is that it could be beneficial to possess more than one language.

Let us start with the advantages of being a bilingual, which has been a hot topic in the past few decades. Not only has the difference of linguistic development between bilinguals and their monolingual peers been studied, but nonverbal cognitive development affected by bilingualism has also been supported by an amount of evidence. Bialystok, Luk, Peets, and Yang (2010) showed that monolinguals are better at linguistic tasks, such as vocabulary assessments than bilingual children despite better metalinguistic awareness found for bilinguals. By comparison, executive control tasks are performed better by bilinguals (Bialystok, 1999; Bialystok, Barac, Blaye, & Poulin-Dubois, 2010; Bialystok & Martin, 2004; Bialystok & Viswanathan, 2009; Carlson & Meltzoff, 2008; Mezzacappa, 2004). However, these effects may be influenced by several variables, for example, socioeconomic differences between bilingual and monolingual children (Morton & Harper, 2007) and cultural effects (Sabbagh, Xu, Carlson, Moses, & Lee, 2006). With this in mind, Barac and Bialystok (2012) compared four groups of children (English monolinguals, Chinese-English bilinguals, French-English bilinguals, Spanish-English bilinguals) on three verbal tasks and one nonverbal executive control task. They found that cultural background did not contribute to the performance of executive control tasks as Chinese-English bilinguals were similar for executive control compared with the Spanish- and French-English groups in this study. Generally, three bilingual groups demonstrated an advantage in executive functioning compared to the monolingual group. Also, Spanish bilingual children showed no difference in scores when compared to monolingual children for linguistic assessment of receptive vocabulary and grammatical structure. Bilingualism may boost to both linguistic and nonverbal cognitive development. However, what can be defined as bilingualism or multilingualism?

1.1 Defining bilingualism

No consensus has been reached to define what bilingualism, or more generally multilingualism is. For example, Bloomfield (1935) regarded bilingualism as the addition of one language. Weinreich (1953) simply defined bilingualism as the alternate use of two languages. Nowadays, the term is often referred to as the ability to speak or understand two or more languages. It can be applied to individuals as well as to an entire society. And it may include late learners, as well as early learners.

There are several classifications of bilingualism. According to the age of acquisition, there are generally two kinds of bilingualism, that is, early and late bilinguals. One may also become bilingual by learning in two different linguistic settings at the same time, which is called simultaneous bilinguals. Another type of bilingualism compared with simultaneous bilingualism is called sequential bilingualism, which, based on the order of second language acquisition, means a person learns one language before another. Apart from the age of acquisition, bilingualism can also be defined in terms of the language proficiency of the speakers. The first one is called receptive bilingualism referring to those who are native speakers of one language and have the ability to understand but not to speak the other. This is often found among adult immigrants from one country to another. Besides, those who are more proficient in one language are called dominant bilinguals. In contrast to the unbalanced bilinguals mentioned above, another type is called balanced bilinguals who have more or less equal proficiency in both the first (L1) and second languages (L2).

When discussing bilingualism, much has to do with the first and second languages. Then what is the first or the second language? How can we define what is native level? According to Hulstijn (2005), a native speaker is socially defined as someone who acquires the language before school age and maintains it into adulthood. In other words, the first language, mother tongue or native language, is the language that someone has learned from birth. It is often an important part of one's personal, social and cultural identity.

Several criteria have been used to define one's native language, for instance, based on function, origin, or competence, to name but a few. Cook (1999) proposed that one can be recognized as a native speaker of a language if he or she has subconscious knowledge of rules, such as phonology, syntax, semantics, to grasp meanings intuitively, to produce fluent discourse, to use the language creatively, and to communicate within social settings.

However, does native language mean someone can perform the language at the native level? Then what is the native level? This often comes together with the terms: language fluency and language competence. The former refers to the ability to produce language on demand and be understood (González, 2008), while the latter, known as linguistic competence (cf. Chomsky 2014), is the linguistic system possessed by native speakers allowing them to understand and produce an infinite number of sentences, as well as to distinguish grammatical sentences from ungrammatical ones in their languages.

1.2 Bilinguals learn to read

Learning to read consists of a complex system including orthographic, phonological and semantic processing. One theory (Williams & Bever, 2010) holds that the phonological awareness plays a key role in reading as the meaning of a new word will be accessible through the phonology-to-semantics link in the oral language system. In alphabetic-phonemic languages, phonological activation is a relatively reliable means of word recognition due to the nature of systematic mapping of sound to symbols.

To support this theory, a large number of studies (e.g. Tan, Spinks, Eden, Perfetti, Siok, & Desimone, 2005) suggested that children's reading ability is governed by their phonological sensitivity serving as a universal mechanism, regardless of alphabetic languages such as English and logographic ones like Japanese and Chinese.

However, another study (Tan, Laird, Li, Fox, & Lancaster, 2005) showed that the relationship between phonological awareness and Chinese characters reading is much weaker than that in alphabetic languages. Instead, other skills, such as (hand)writing can account for successful reading acquisition in Chinese. This proposal is also supported by Chung, Ho, Chan, Tsang, and Lee (2011) as well as Siok and Fletcher (2001) that orthographic awareness is more powerful than phonological awareness in predicting successful Chinese reading. This might be because the underlying mechanism in Chinese acquisition is through visual processing of a character's configuration and discovery of orthographic structure (Luo, Chen, Deacon, Zhang, & Yin, 2013).

1.3 Reading Mandarin Chinese Characters

Belonging to a logographic language system, the orthography of Chinese characters can be described at different levels, namely, strokes, radicals, characters, and words (Taft & Zhu, 1997). The radicals in Chinese are called 偏*pian1*, 旁*pang2*, 部*bu4*, 首*shou3*, standing for side, component, part, and head respectively, which indicates their spatial positions in the character (Chen, 1993). There are normally four positions for different radicals, left, right, top, and bottom. For a left-right structure character, the left-hand radical normally stands for the meaning of the character, also known as the semantic radical, while the right-hand indicates the pronunciation of the character, known as the phonetic radical. Moreover, the formation rules of Chinese characters can be classified as follows: imitative, indicative, ideo-compound and ideo-phonetic. Imitative refers to the formation of written characters through the picture of real objects (e.g. 日 *ri4* sun). The indicative rule stands for the formation of symbols which can indicate the meaning (e.g. 上 *shang4* up). Ideo-compound refers to the combination of the meaning of two components resulting in a new character (e.g. 好 *hao3* good=女 *nǘ3* woman +子 *zi3* child), in which no orthographic unit represents the pronunciation. Ideo-phonetic refers to the composition of characters by combining one radical standing for the semantics and the other for phonetics (e.g. 村 *cun1* village=木 *mu4* wood+寸 *cun4* inch). The majority (about 81%) of Mandarin Chinese characters are semantic-phonetic compounds, which consist of semantic radicals and phonetic radicals (Chen, Allport, & Marshall,1996). The semantic radicals are usually located at the left-hand side (the former example) or the top of the character, such as 雨 *yu3* 'rain'+路 *lu4* 'road'= 露 *lu4* 'dew', which is used for identifying the semantic elements. The phonetic radicals, on the other hand, are usually located at the right-hand side or the bottom of the characters. However, the pronunciation of a Chinese character cannot always be achieved by phonetic radicals even though the same radical may appear in the same position of a character. For instance, 马 *ma3* horse in 妈 *ma1* mother and 冯 *feng2* a surname. As for the semantic radical, it cannot be said to specify the whole meaning of the character but only give hints to certain features or semantic categories. As a result, the recognition of Chinese characters is not simply achieved by phonology or semantics of the radicals alone and is still a controversial topic.

As the semantic meaning is embedded in the characters themselves, such compositional structure might require Chinese readers to develop reading strategies different from readers of alphabetic scripts. For instance, Mandarin Chinese native speakers learn reading and writing skills through word-by-word memorization and frequent repetition (Chan, 1999). Besides, they exhibit a large reliance on visual information in word recognition (Chikamatsu, 1996). According to Shu and Anderson (1997), learners of Chinese depend on semantic radicals of characters to determine semantic information. Literate readers also make use of semantic radicals for recognizing less commonly used characters rather than phonological components. Therefore, reading Chinese seems quite different from that of readers of alphabetic languages. It is argued by several researchers that there might be a dual-route to lexical recognition of a character, that is, one being direct access through the relationship between orthography and semantics of the character, the other being indirect access through the character's phonology (Zhou & Marslen-Wilson, 2000).

Evidence can also be found from neuroscience studies regarding dyslexia in alphabetic languages and logographic counterparts. For example, Ho and Fong (2005) reported a boy being dyslexic in Chinese, but not in English. McBride (2019) also reported dyslexia in Chinese but not in English, which may indicate two different routes for processing the alphabetic coding and ideographic coding. Several reports (Bolger et al., 2005; Huang et al., 2012; Tan et al., 2000) suggested the different parts of brain activities between dyslexia in Chinese and that in English. For Chinese dyslexics, the left dorsal lateral frontal region has been identified as this part is responsible for visuospatial analysis and orthography-to-phonology mapping, whereas the left posterior temporo-partial has been found responsible for alphabetic languages like English, which mediates graph-to-phonology conversion and fine-grained phonemic analysis. In other words, the areas of the brain for Chinese dyslexics dedicate to identifying images and shapes, while those for English counterparts are associated with converting letters to sounds. Nelson et al. (2009) studied English learners of Chinese and found the activity in the bilateral fusiform gyri for reading characters, while only left fusiform gyri has been activated while they read English.

1.4 Research Questions and Hypotheses

The above-mentioned background information about reading in alphabetic languages and logographic Chinese demonstrate different linguistic features. Unlike reading alphabetic languages which always requires mapping of visual form to its auditory form during early stages of lexical access in terms of Levelt's model (more details see Chapter 2), the lexical access of logographic Chinese characters might be a different picture. Whether the reading of characters can be independent of phonological encoding remains debatable. How these differences reflect the mental representation of Chinese native speakers who can speak other alphabetic languages would be an interesting issue.

Among all the methods to study mental representations of bilinguals or multilingual, priming is economic and has strong operability. Priming effects were found for cognates and interlingual homographs, also known as false friends, in orthographic similar languages such as Dutch and English (Lemhöfer and Dijkstra, 2004). However, it is still unknown whether such effects can be observed in orthographic dissimilar languages. In the pilot study of Norwegian-Chinese priming lexical decision (Yang & Johanson, 2019), neither form nor meaning effects was found from Norwegian to Chinese. It is, however, still unclear if the finding was due to the proficiency of the participants or particular to the experiment.

This study aims at further investigating form and meaning aspects of cognate, false friend, translation and unrelated word pairs in contrast to the unprimed counterparts. This will be achieved by recording the reaction times collected from a series of cross-linguistic lexical decision task under the masked priming paradigm in which different conditions will be compared, namely, +/- meaning and +/- form. The findings of this study will be interesting to confirm whether form or meaning will be the reliable link for speakers from different orthographic language system and how important is phonology in lexical access of Chinese characters and whether words from orthographic different languages are stored together or separately.

To wrap it up, the hypotheses of the current study will be:

1. Neither form nor meaning priming effects of Norwegian words will be found for Chinese native speakers, which is the null hypothesis of the study.
2. Asymmetric effects will be observed in different language directions, which has been supported by several studies (Chen & Ng, 1989; Jiang & Foster, 2001) on semantic cross-linguistic priming.
3. Meaning-related word pairs will show stronger priming effects than form-related pairs regardless of language directions since the RHM model suggested that meaning is the link for bilinguals (more detail see Chapter 2).
4. Rejecting nonwords in both English and Norwegian will be significantly faster than in either English or Norwegian.

1.5 Outline of the thesis

The previous sections have given a background of the research questions, as well as definitions of key terms. The following sections will be organized as follows:

Chapter 2 will mainly focus on the theories of bilingual and multilingual mental lexicon, from models of mental representations, bilingual and multilingual processing to models of visual word recognition. Chapter 3 will describe research methods and procedures as well as experiment stimuli, followed by the results of each experiment presented in Chapter 4. The interpretation of results and their implications will be discussed in Chapter 5. The last chapter (Chapter 6) will conclude by taking into account all previously discussed issues.

Chapter 2 Theoretical foundations

Mental representations of bilinguals and multilinguals could be one of the most controversial topics in the field of psycholinguistics. Besides, how bilinguals recognize words would be another issue experiencing hot debate. Before going into a more detailed discussion regarding bilingual and/or multilingual models of language representation and lexical access, the explanations of these key terms will be necessary.

What is mental representation? The term refers to the internal cognitive process making use of the external symbols that can describe and explain the concepts (Morgan, 2014). Linguistically, mental representation is associated with semantic memory in which language may have an impact on or shape the mental representations of semantic information (Hubbard, 2007). In this study, mental representation refers to how words from two or more languages are represented in our mental lexicon. Then, what is the mental lexicon? It is a systematic and organized mental store of lexical items through which words related to specific concepts can be accessible easily (Aitchison, 1987).

Models with regards to mental representation, namely shared or separate language stores will be discussed in sections 2.1 and 2.2. How words access the mental lexicon will be described in 2.3. Section 2.4 will focus on the models about visual word recognition and the last section (section 2.5) will discuss models in association with multilingualism.

2.1 Mental Representation of Bilingualism

A key issue concerning the mental representation of bilinguals is whether languages are stored together or separately. Based on Saussurean's distinction between signifier and signified, the first models of structures of bilingual language processing were proposed by Weinreich (1953). The signifier refers to the word-form representation, while the signified is the concept or the meaning of a word. The main focus of Weinreich's three hypotheses, namely, coordinate, compound, and subordinate bilingualism, were focusing on the conceptual storage and form representation of bilinguals.

For a coordinative bilingual, two languages are separate and independent at both word-form and conceptual level. In other words, each signifier correlates to one signified. For example, Weinreich (1953) gives an example that the English word *book* /buk/ and the Russian word *kniga* /kni,ga/ represent meanings that may be unique in each language without sharing a lexicon and no interaction can be found between these two languages on a conceptual level as shown in figure 2.1. Thus, this type of bilingualism is sometimes regarded as pure bilingualism.

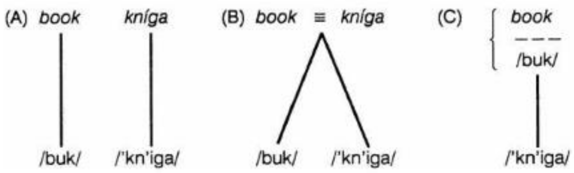

Figure 2.1 Coordinate (A), Compound (B), Subordinate (C) Bilingual Mental Representation Weinreich (1953)

The compound configuration, on the other hand, proposes that information at the word-form level is independent while information at the conceptual level is shared Weinreich (1953). This means that one signifier has two signified, that is, two words share a common conceptual representation. For an English-Russian bilingual, for example, there are two different forms, *book* and *kniga*, representing one meaning on the surface, but the underlying concept would be the same across two languages.

Similar to the compound bilingualism hypothesis, the subordinate system assumes that there is only one conceptual store, but the second language is just the translation equivalent of the first language before accessing the conceptual store. This architecture suggests that the signified of the second language is simply the translation equivalent of the word in the first language and only the signified of the first language has the access to the signifier at the conceptual level. As can be seen from figure 2.1, the Russian word /kniga/ associates with its English translation equivalent /buk/ through which can the Russian word be correlated to the concept ‘book’.

Despite these classifications, it is important to note that the human cognitive system is dynamic. It is also true for the bilingual mental representations. Further argued by Weinrich himself (1953), a bilingual’s proficiency level and how he learned the second language may affect the structure of his/her language representation. A subordinate bilingual system may develop into a coordinative and/or compound bilingual structure through practice. The more proficient a bilingual speaker is, the more likely it is for the subordinate to be shifted to the coordinate or compound.

Ervin and Osgood (1954) further considered the influence of acquisition or learning context on bilingual language architecture. Specifically, different learning settings may have great impact on the bilingual’s language storage, for example, learning at home or school, whether two languages belong to two different cultures, or whether L1 and L2 were learned in one country or two different countries if L2 was learned through L1 or L2 instructions. It is more likely for a bilingual’s two languages to be stored independently if he/she learned L2 at several different acquisitional contexts (Macnamara, 1967).

The coordinative system is developed in a situation where two languages are learned in two different learning settings (Gekoski, 1980). For instance, L1 is learned at home while L2 is learned outside, such as at school or workplace. Besides, coordinative bilingualism emerges when L2 is learned in a cultural context different from where L1 is learned. For instance, Heredia (2014) illustrated the difference between the Spanish word *librería,* a book store, and the English word *library*. If the Spanish word is learned in Mexico, the conceptual representation of *librería* might involve information about anything related to a place where materials associated with the study are sold, such as books, notebooks, pencils, etc.. However, if the word *library* is learned in an English school setting, the semantic representation might contain things concerning school libraries, like library cards, self-study rooms and so forth.

The compound bilingualism, on the other hand, emerges when two languages are learned in the same contexts, for example, bilingual homes in which a bilingual child speaks two languages interchangeably (De Groot, 1993). Alternatively, learning L2 words through the translation equivalents in L1 will eventually develop this kind of bilingual structure as the link between L2 and the concept grows stronger.

2.2 Shared storage models Vs separate storage models

Whether there are one or two conceptual storages for bilinguals has become a central topic discussed by several linguists in the following years after Weinreich's (1953) three models. The most debatable one would be the separate storage and shared storage models developed by Kolers (1963).

The separate storage model postulates that L1 and L2 are stored separately in two separate language-specific representational systems. Using word association, recall tasks, some earlier studies (e.g. Lambert, Havelka, & Crosby, 1958; Lambert, Ignatow, & Krauthamer, 1968) indeed found support for the assumption of two separate language systems. Lambert at al. (1958) found different associations from the English-French word pairs *church-eglise*. For an English-French bilingual who has lived in France before moving to English dominant settings, the French word might be associated with a cathedral whereas the English word church may mean a tall wooden building used on Sundays.

However, recent studies using lexical decision tasks, Stroop tests and semantic categorization have revealed the limitations of the separate storage model. For instance, Jin (1990) tested Korean-English bilinguals and monolinguals through lexical decision tasks. He found substantial priming effects for concrete words rather than abstract words for both the bilingual group and the monolingual counterpart, suggesting that not all words are stored independently. Concrete translation equivalents are integrated through a common representation in the bilinguals' mental lexicon.

The limitation of the separate storage hypothesis is further supported by de Groot and Nas's (1991) examination of Dutch-English bilingual mental lexicon through masked and unmasked priming for cognates and noncognates. The significant priming effects for cognate stimuli suggested that cognate translations shared conceptual representations, while the absence of priming effects between noncognates from two languages pointed out that noncognate translations were represented in separate conceptual nodes.

These modifications of the separate storage models are known as the word-type effect, which is further explained in the distributed model proposed by de Groot (1995). Within this model, some types of words may share conceptual representations, whereas other types may have separate storage. The distributed representation is illustrated in figure 2.2, where concrete and cognate words in L1 and L2 may share some conceptual nodes as shown in C2, C3, and C4, while abstract and noncognate words may be linked to separate nodes as in C1 and C5.

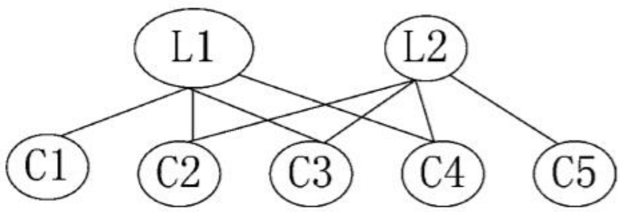

Figure 2.2 Distributed Model by De Groot (1995). L1 and L2 stand for words in the first and second languages of a bilingual. The nodes C1 to C5 represent five conceptual components, of which C2, C3, C4 are shared whereas C1 and C5 are separate.

The previously discussed models differ from the other three models in whether there is shared storage or not. The following models will focus on the contrast between two specific shared storage models. To begin with, the word association model holds that there is a direct word-to-word connection between the first and second language, and only through the L1 translation equivalent can speakers access the meaning of L2 (Potter, So, von Eckardt and Feldman, 1984). This is often found among bilinguals when their second language is weaker than their first language. The concept mediation model, on the other hand, proposes a single conceptual system for two languages and that L2 words, independent from L1 words, can access this conceptual representation directly (see figure 2.3 below).

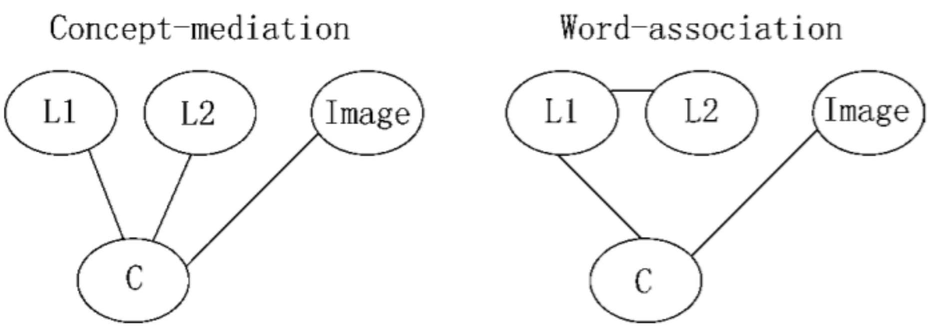

Figure 2.3 Word concept mediation model and word association model proposed by Kroll and Stewart, 1994, p.150.

To prove the validity of the models, Potter at al. (1984) compared picture naming in L2 with the translation of L1 into L2 between a more proficient group of Chinese-English bilinguals and a less-proficient group of English-French bilinguals. In their study, both the picture naming and translation tasks were performed equally fast by two groups of participants, providing evidence for the concept mediation model hypothesis.

However, later studies suggested (Chen & Ho, 1986; Kroll & Curley, 1988; Chen & Leung, 1989; Abunuwara, 1992; de Groot & Hoeks, 1995) modifications for Potter's conclusion regarding the concept mediation model. For instance, Kroll and Curley (1988) tested novice bilinguals and found out that translation of L1 into L2 was faster than picture naming in L2, ensuring the validity of the word association model. They argued that early stages of second language learning rely on word association between two languages and Potter et al. (1984)'s conclusion only accounted for individuals who did not pass the critical learning period of the second language.

Similarly, de Groot and Hoeks (1995) examined unbalanced trilingual adult speakers with Dutch as their native language and L2 English stronger than L3 French. They tested the assumption of a concept mediation structure for the native language and stronger foreign language, while a word association structure for the native language and a weaker language. Participants were asked to translate L1 Dutch into L2 (English) and L3 (French). The results showed a concreteness effect in translating Dutch to English (L1 to L2), providing support for the concept-mediation hypothesis. However, no such effect was found in Dutch-to-French (L1 to L3) translation, supporting the word association model. The results from Kroll et al. (1988) and de Groot et al. (1995)'s studies point out the possible shift from reliance on word association at an early stage to concept mediation with greater proficiency in the second or third language.

As the third type of the shared storage model, the Revised Hierarchical Model (RHM), developed by Kroll and Stewart (1994), takes into account aspects of both word association and concept mediation models, along with additional information about the asymmetrical word-to-word and word-to-concept relationship between L1 and L2. The model postulates that the link between L1 and the shared concept is stronger than the link between L2 and the shared concept. This is because a strong link has already been established between the first language lexicon and conceptual memory before a person starts to learn a second language beyond the so-called critical period. During the early stage of second language learning, L2 words are associated with the translation equivalents of L1. As the speaker becomes more proficient in L2, the direct links between L2 and concepts will become clearer. Therefore, at the lexical level, the connection from L2 to L1 is stronger than that from L1 to L2.

Evidence for and against the revised hierarchical model comes from the studies of word translation. Kroll and Stewart (1994) examined fluent Dutch-English bilinguals. Participants were asked to name pictures in either Dutch or English and translate from one language to the other. Two conditions were set for the experiments: words were blocked by semantic category and words were randomly mixed. Interference will be found in the categorized condition if the translation relies on concept mediation. However, categorical interference was found only for forward translation (L1 to L2), while no interference could be seen from L2 to L1. This suggests that translation from L1 to L2 requires concept mediation, whereas translation from L2 to L1 largely relies on the lexical association. In other words, L1 words are more likely to activate the conceptual representations, whereas L2 words tend to activate the L1 translation equivalents. Such features have been regarded as the evidence for the revised hierarchical model by Kroll and Stewart (1994), illustrated in figure 2.4.

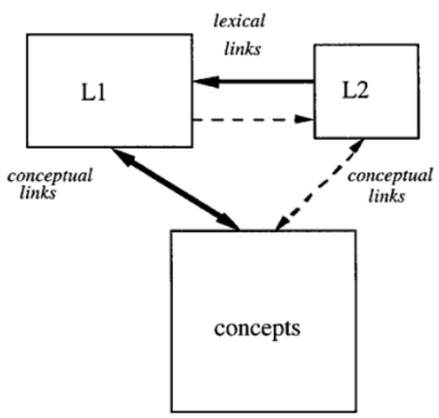

Figure 2.4 Revised Hierarchical Model by Kroll and Stewart (1994)

Not all the studies are in agreement with the revised hierarchical model hypothesis. Therefore, a series of work tried to retest the model. For example, de Groot and Poot (1997) tested three groups of unbalanced bilinguals through the translation task from Dutch to English (L1 to L2) and from English to Dutch (L2 to L1). Contrary to the asymmetrical model proposed by Kroll and Stewart (1994), the longer response time has been found for the backward translation (L2 to L1) than for the forward translation (L1 to L2). Also, word imageability and concreteness showed that both directions involved concept mediation. However, fewer errors and more omissions were found in the forward translation than in the backward translation, which was in accord with the weak version of the revised hierarchical model (de Groot & Poot, 1997).

So far, it seems that bilinguals relying on shared conceptual storage have been favored by most researchers and match up with people's intuition. However, it is a mistake to assume that the issue has been well solved. Evidence for separate storage has been supported by studies using other methods, such as fMRI and PET. For example, Ojemann (1989) has shown that areas responsible for L1 response and those for L2 response can be distinguished through an electrical simulation of the cortex. Even for behavioral studies like de Groot and Nas (1991), the obtained data suggested that cognate translations share conceptual representations, whereas noncognate translations have separate conceptual representations. Neither the separate storage models nor the shared storage models focused on discussing and testing how two languages interact. Thus, models concentrating on the interactions between languages emerged.

2.3 Lexical Access

Previous sections discussed models on the shared storage in contrast to the separate storage of bilingual mental representations. How words get access to the mental lexicon in bilinguals' minds is of equal importance as mental representation in the study of language acquisition. Thus, models of lexical access will be the focus in the following sections. Specifically, the lexical access hypothesis will be discussed in 2.3.1, followed by the debate on the selectivity of lexical access in section 2.3.2.

2.3.1 Lexical access hypothesis

To get a better insight into interactive models, which aims to describe the processes governing lexical selection, it is necessary to understand what is lexical access.

Lexical access, proposed by Levelt (2001), is defined as how individual words are accessed in the system of vocabulary organization in the human brain. Such an organization is called a mental lexicon. Based on the computational implementation, Levelt (2001) developed a model of speech production and lexical access involving the process from the beginning stage focusing on a concept to the stage of syllabification before articulating the corresponding concept.

The speech production model consists of a serial two-system architecture, as shown in figure 2.5: lexical selection, in which appropriate items for concepts will be selected from the mental lexicon, and form encoding, where the selected lemma will be prepared for articulation. Within the lexical selection stage, the first step, also called perspective taking, is to retrieve the lexical concept with a particular communicative goal (Levelt, 2001). To explain this activity, the picture naming task was used as an example, where participants will be shown a picture and be asked to choose between the possible words to describe the picture. For instance, what is the name for a picture of a horse? Is it a horse, stallion, or an animal?

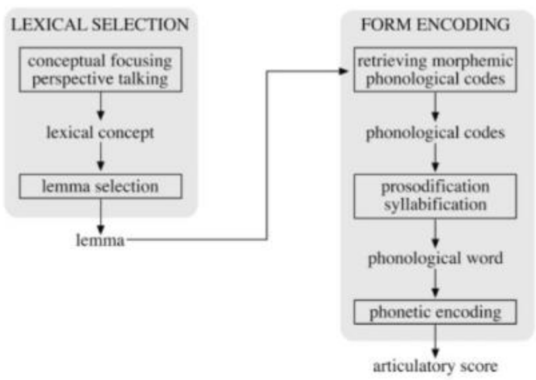

Figure 2.5 Serial Two-System Architecture by Levelt (2001, p.13465)

Related concepts, also presented in the mental lexicon, are co-activated during the perspective-taking stage. The active lexical concepts spread activation to corresponding lexical items in the speaker's mental lexicon which are called lemma (Levelt 2001: 13464). Lemmas are conceptual forms with specific meanings but without specific sounds. They are usually coded with syntactic properties, for example, gender (feminine or masculine), number (singular or plural). However, several lemmas will compete with each other as some may share the same syntactic properties. Once the target lemma is selected, the lexical selection is completed, which triggers the next process, that is, form encoding.

Three stages together form the process of form encoding. During the first stage, the activated lemma spreads activation to the related phonological codes. If a lemma has a multimorphemic code, the phonological code is retrieved for each of the morphemes. For example, the plural form horses will be retrieved for /horse/ and /iz/. The spelled-out phonological codes consisting of the ordered sets of phonological segments form the input of prosodification or syllabification to a large extent. Dependent on the current context and not stored in the mental lexicon, an item's syllabification is subject to change according to its syntactic properties, for instance, the syllable of the singular form horse cannot be the syllable for the plural form horses. After syllables are incrementally produced, the final output of phonetic encoding and articulation is completed, leading to a pronunciation of a specific word.

2.3.2 Selective Vs Non-selective access

Several of studies (e.g. Soares and Grosjean 1984; Gerard and Scarborough, 1989) on whether lexical access is selective or non-selective have been debated for decades. Early studies seem in favor of selective access. Caramazza and Brones (1979) conducted research on Spanish-English bilinguals to see their reaction times to the tested items under three conditions. No differences between reaction times were found of words with identical graphemic structures but different phonological structures, referred to as cognates in their study, were detected, giving support to the selective access position.

Recent studies have provided substantial evidence for non-selective lexical access view. For instance, Dijkstra, van Jaarsveld and Ten Brinke (1998) have found a facilitatory effect for homographs, despite no significant difference in reaction times, indicating language access might be non-selective. One year later, Dijkstra, Grainger and van Heuven (1999) conducted experiments on Dutch-English bilinguals through a lexical decision task and found faster reaction times to cognates and interlingual homographs. Lemhöfer and Dijkstra (2004) found that cognates were recognized faster than the matched English and Dutch controls. Apart from the behavioral studies, findings from neurolinguistics also provided important information to support the non-selective hypothesis. The eye-tracking analyses by Marian and Spivey (2003), Bartolotti and Marian (2012) as well, showed early activation of both languages for bilinguals.

In sum, the research results in recent decades demonstrate the activation and competition between languages in the bilinguals' memory, which further suggests that the lexical access is non-selective.

2.4 Bilingual Visual Word Recognition

Previous sections discussed the storage of bilinguals' mental representation, whether lexical access is selective or non-selective. This section will describe how bilinguals recognize visual words, which is an essential part of the current study since the word stimuli used in the present research are orthographically different.

2.4.1 Interactive activation model and its effect on the BIA model

Proposed by McClelland and Rumelhart (1981), the monolingual interactive activation model focused on visual word processing and investigated the retrieval of orthographic representations from the mental lexicon corresponding to the input letter string. According to the model, the system is composed of several levels for perceptual processing with a node representing the input at each level. Specifically, a visual feature level, a letter level, and a word level, as well as higher levels are involved in the top-down input. Besides, visual processing occurs at several levels simultaneously. Activation at each level of processing inhibits or facilitates the activity in neighboring levels. One of the important features of this model is that both the target word and its relevant information are co-activated. As a result, the recognition of the stimulus has been reinforced. Figure 2.6 shows the general conception of the model.

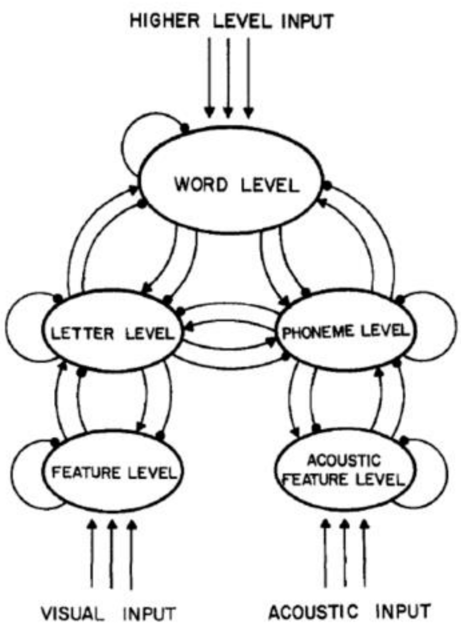

Figure 2.6 Interactive activation model: bottom-up visual and acoustic input as well as top-down level semantic input (McClelland & Rumelhart, 1981, p. 378)

Sharing basic structure and parameter settings of the monolingual interactive activation model, Dijkstra and Van Heuven (2002) proposed the Bilingual Interactive Activation (BIA) model aiming at issues that do not apply in the monolingual domain. For instance, the first issue is concerned with whether lexical candidates are activated from both languages or just one language during the bilingual word recognition. The second issue deals with the storage of lexical representations of two languages, that is, whether the representations are stored together in one single lexicon or different lexicons.

The basic assumption of the BIA model holds that lexical access is non-selective and bilingual mental lexicon is integrated across languages (Dijkstra & Van Heuven, 2002). Like the IA model, the feature, letter and word level are connected. Compared with the Interactive Activation model, however, an extra level of nodes representing two languages has been added, see figure 2.7. The feature of each letter is affected by the visual input when being presented with a string of letters. Letters containing these features will be activated while those without the features will be inhibited. The activated letters further spread its activation to relevant words in both languages. At the word level, the nodes from the same language send activation to the corresponding language node, while inhibiting all word nodes from other languages. Finally, activation from words in one language has been collected at the language nodes, while others are inhibited.

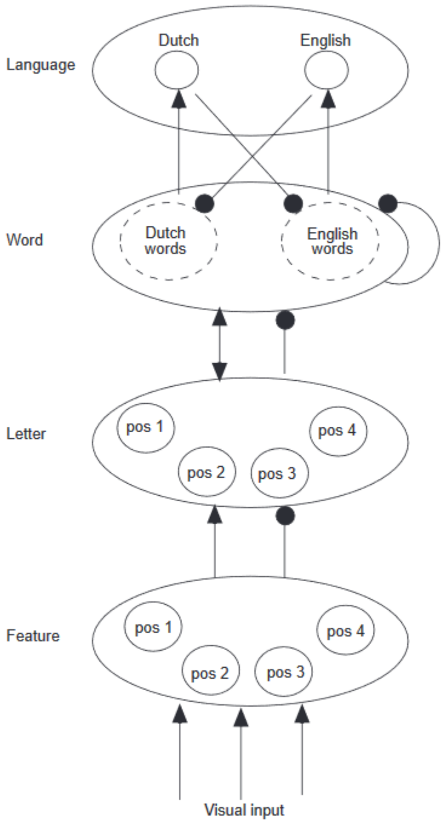

Figure 2.7 The Bilingual Interactive Activation (BIA) model for bilingual word recognition. Arrowheads indicate excitatory connections; black dots indicate inhibitory connections (Dijkstra & Van Heuven, 2002, p.177).

The additional language nodes in the BIA model, argued by Dijkstra and Van Heuven (1998), serve as linguistic representations and as non-linguistic functional mechanisms. For the linguistic functions, the language nodes are assumed to collect activation from the lexical representations within a language. For the non-linguistic functions, the language nodes serve as language filter and contextual pre-activation. As contextual pre-activation, the nodes can collect activation outside the word recognition, such as the expectations of the participants with respect to the input materials to be processed (Dijkstra & Van Heuven, 2002, p. 177).

The BIA model can simulate empirical effects such as neighborhood effects, language proficiency, etc. Orthographic neighbors are defined as any word differing by a single letter from the target word in length and letter position (Coltheart et al., 1977). To put it another way, for instance, they can be words sharing three letters with a four-letter target word, like *word* and *work*. By examining Dutch-English bilinguals, Van Heuven et al. (1998) found out longer response times for English target words when the number of Dutch orthographic neighbors increased. Such a result is the indication of co-activation for neighbors from both languages, which further gives support to the non-selective integrated lexicon of bilinguals just as the BIA model proposed. Besides, in another lexical decision task (Dijkstra & Van Heuven, 2002), facilitatory effects were found when primed words and target words were orthographically dissimilar, whereas inhibitory effects were found when primes and targets were similar in their orthography.

Although the BIA model successfully simulated previously discussed effects, there are still limitations to be taken into account. For instance, no phonological or semantic representations have been simulated in this model; the influence of non-linguistic and language contexts on bilingual word recognition has been underspecified; to name but a few. As a result, the extension of the BIA model is urgent, giving rise to the BIA+ model.

2.4.2 The BIA+ model

The Bilingual Interactive Activation Plus (BIA+) model is the extension of the BIA model with additional representations and processing components, see figure 2.8.

It is the first model to account for the interactions between orthographic, phonological and semantic representations, the representation of interlingual homographs and language membership tags, as well as the effects of linguistic and non-linguistic context on participants. For instance, the activation of orthographic codes is the same as the BIA model during the first stages. The activation of lexical orthographic input depends on the similarity to the input string, the resting level, subjective frequency, recency of use and L2 proficiency. Next, the activated orthographic representations excite their phonological and semantic correspondence. The overlap between the input string and representation in the mental lexicon determines the degree of activation. In other words, if two languages are similar in their input codes, the activated set of neighbors may be larger than two languages that differ on their orthographic input. For example, Chinese orthography may not activate much of the alphabetical letters.

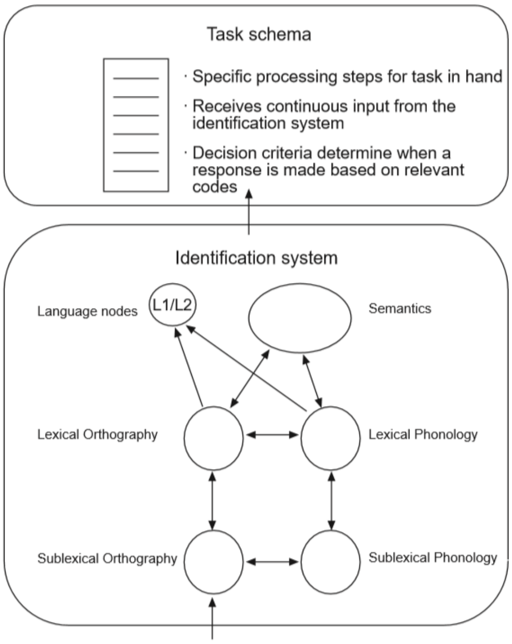

Figure 2.8 BIA+ model for bilingual word recognition (Dijkstra & Van Heuven, 2002, p. 182)

The activation of phonological and semantic codes is assumed to be later than that of orthographic codes, as they depend on subjective frequency. Such a delay is called temporal delay assumption (Dijkstra & Van Heuven, 2002). This is the result of larger cross-linguistic effects from L1 to L2 than in the opposite direction. Besides, if reacting faster to the L1 orthographic codes, there is a chance that no phonological and semantic effects can be found across languages.

The BIA+ model differs from the BIA model also in its consideration for interlingual homographs and cognates. Do identical homographs in two languages share one representation or have different representations? The cross-linguistic facilitatory effects observed by Dijkstra et al. (1999) indicates the shared representations for lexical items in two languages. The strong inhibitory effects, on the other hand, were found for interlingual homographs when L1 reading of the homographs had a relatively higher frequency than the L2 reading Dijkstra et al. (1998). This suggests that the lexical items from two languages may have distinct representations. The assumption is also supported by Lalor and Kirsner (2000), as well as Sáchez-Casas, García-Albea and Davis (1992) that a common morphemic representation may be found in cognates irrespective of languages. Consequently, the BIA+ model assumes that interlingual homographs have distinct representations instead of shared ones in spite of no consensus being reached for cognates in this regard.

So far, we have taken a detailed look at models regarding how bilinguals' mental lexicon works and whether there is a shared storage or a separate storage for conceptual representations. We will now move on to the processing of the mental lexicon of multilingual as the current study focuses on Chinese native speakers with English as their second language and Norwegian as the third. Will the mental representation of the third language be different from the second one?

2.5 Multilingualism

Third language acquisition plays a key role in connecting multilingualism and second language acquisition. In early studies, Mägiste (1985) conducted experiments comparing the language processing speed among monolinguals, bilinguals, and trilinguals. Several tasks were used, for example, a picture naming task and a two-digit number naming task, as well as reading aloud printed words. Her data showed that the trilingual group performed more slowly on most of the tasks compared with the monolingual and bilingual groups. Alternatively, an extra language may create more competitors. This will slow down decisions more when there is no clear winner.

Recent empirical findings in the field of multilingualism have shown that the mental lexicon of a language learner does not consist of separate entities, but rather of an intertwined system where languages can interact with each other (e.g. Cenoz, 2013; Szubko-Sitarek, 2015).

2.5.1 Multilingual Mental Representation

Based on language proficiency, Gabrys-Barker (2005) proposed a multilingual adaptation of Kroll and Stewart's Revised Hierarchical Model by conducting a series of association tests to Polish-English-German and Portuguese-English-German trilinguals. In this model, depicted in figure 2.9, the lexical links and conceptual links are considered to connect items in multilingual memory. It is argued by Gabrys-Barker (2005, p.64) that words in multilingual memory are accessed either through lexical links or conceptual links depending on different factors, for instance, language dominance in the multilingual competence and performance of a learner, language proficiency in all the languages, the form of a linguistic task, and the type of a linguistic stimulus. He further concludes that there is an integration of L1, L2 and L3 mental lexicons, which is also called the degree of cross-lexical connectivity.

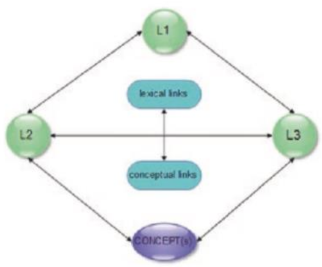

Figure 2.9 Model of multilingual memory representation (adapted from Gabrys-Barker 2005, p. 64)

To further account for what he called the degree of cross-lexical connectivity and to design a multilingual mental representation model, it is important to explore the similarity between new lexical input and previous lexical knowledge. The Parasitic Model put forward by Hall and Ecke (2003) explained the influence of L2 vocabulary acquisition on later L3 vocabulary acquisition. Specifically, the automatic, unconscious detection and adaptation of similarity between new lexical input and the information already stored in the mental lexicon are involved during the initial stages of additional language vocabulary acquisition. According to the Parasitic Model, "*new lexical representations will be integrated where possible, into the rest of the network via connections with pre-existing representations (...), at points of similarity or overlap between them*" (Hall & Ecke, 2003, p. 72). For example, it is more likely for a third language learner in German to connect the German verb *brechen* to the L2 English word *break* rather than the L1 Spanish word *romper* at the early stage of vocabulary learning due to the cognate relationship between German and English. As a result, there is a chance that the learner assumes the German verb *brechen* preceding a non-reflexive pronoun instead of a reflexive pronoun, which is similar to its English cognate (Hall et al. 2003). In all, the model concludes that lexical representations, irrespective of the language, are connected in terms of similarity and the mental lexicon is interconnected.

Further development of the Parasitic model is proposed by Herwig (2001) who advocates that there are three identical, but language-specific networks to form a single system. To be specific, the learning of L2 strongly relies on L1 at the initial stage. However, as L2 becomes more proficient, the connection will be less dependent and will extend into a 'fairly independent subsystem'. The same pattern of learning also applies to third language acquisition. This is because of the typological closeness between L3 and L2 or L1.

In the light of Weinreich's subordinate model of bilingualism, Singleton (2002) focuses on the subordination of L3. In his case of English-Spanish bilinguals learning Italian as the third language, Italian lexical forms are connected to Spanish due to the typological closeness between these two languages at an early stage. As the progress goes on, it is likely for Italian items to share the same concepts with Spanish words, which develops a compound structure. Finally, when three languages become proficient to the relative same degree, a coordinate structure will emerge. This means that either at the lexical or the conceptual level, each language has a language-specific representation. However, there are connections among these representations through which the transfer from one language to another will be realized.

Although no consensus has been reached on multilingual mental representations, the majority of research, discussed above, seems in favor of interconnected language systems within one mind. Apart from the lexical representations of multilingualism, multilingual lexicon processes have gained much interest in recent years, for instance, the extension of Levelt's lemma selection by de Bot's Multilingual Processing Model (2004), Müller-Lancé's Connective Model (2003) and the Li Wei's model of multilingual lemma activation (2003).

Dijkstra's Trilingual Interactive Activation (TIA) model (Dijkstra, 2003a) focuses on the processing of written language performed by multilingual. Similar to the BIA model, the TIA consists of four levels of representations: a feature level, a letter level, a word level, and a language level, see figure 2.10. Like the BIA model, the process starts when the feature nodes at the feature level detect the features of the input letter string and activate the letters that match the input feature and inhibit the unmatched ones. Similar to the BIA model, the activation is marked by arrows and inhibition by black dots depicted in figure 2.10. Similar procedures are repeated among the rest of the levels.

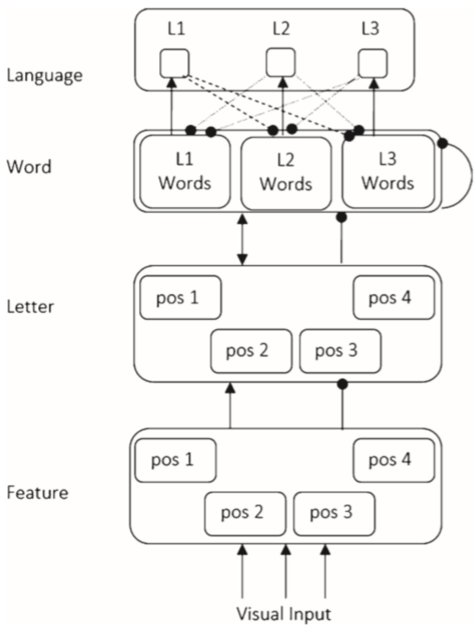

Figure 2.10 Trilingual interactive activation model (adapted from Dijkstra, 2003a)

Within the BIA model, an important hypothesis is the neighborhood effect, that is, words with more sharing orthographic forms are more likely to be activated than those without sharing forms. In the case of three languages, the competition between words seems stronger. However, Dijkstra (2003a) only found an average of 30ms slower for L1 recognition, suggesting that not all words are affected by adding items from another language in the mental lexicon. Another factor that might influence the speed of word processing is the distance between languages in the lexical space. Argued by Dijkstra (2003a) that less interference will be seen by words from more distant languages even though they may share the same orthographic forms.

In addition to the bottom-up factors, top-down factors are also crucial in influencing the speed of word processing. The top-down factors, suggested by Szubko-Sitarek (2015), including linguistic ones, such as morphological representations, sentence-level information, or language membership information, as well as non-linguistic ones such as context, task demands, and stimulus list compositions, are all crucial in deciding the speed of word processing. To sum up, no matter what factors affect the word recognition process, more empirical analyses are needed to understand how multilinguals cope with the relatively greater load of word processing in their mental lexicon.

Chapter 3 Methodology

Many experimental methods and techniques have been adopted to discover and explain how our mental lexicon works. For instance, neurolinguistic methods, such as fMRI, ERP, and EEG, have been used to study the activated patterns in the brain. Another less expensive behavioral method, reaction time study, is more frequent in psycholinguistic research. To investigate bilingual lexical memory, the use of priming has become increasingly popular among researchers. Within several different tasks in the priming paradigm, lexical decision tasks have emerged to collect response time to different stimuli, as it could provide insight into mental processes and how languages may be connected.

This chapter will give an outline of how the experiments in this study were designed. Priming paradigm, along with the comparison between masked and unmasked priming will be introduced in 3.1, followed by the experimental procedures and experimental design (see section 3.2). The equipment used in this study will be described in section 3.3 and the stimuli will be introduced in detail in the following part (section 3.4).

3.1 Priming paradigm in lexical decision tasks

Priming is a measure used in psychological studies to explore the influence of one stimulus on the unconscious response to the subsequent stimulus. It was first put forward and implemented by Karl Lashley in 1951 to explore what he called 'the state intervening between the act of will or intention and the production of the intended behavior' (Bargh, 2014, p.3). Favored by his followers, the priming method entered experimental psychology.

A typical priming paradigm involves two phases: a priming phase, in which a list of items (words, sentences or pictures) were presented to participants, and a test phase, where participants are asked to give responses to other stimuli (words, sentences or pictures in the same language).

Despite priming had long been used, it was until 1971 for priming to be adopted in lexical decision task by Meyer and Schvaneveldt (1971) for the first time, where they found out faster reaction times to associated word pairs (BREAD-BUTTER) than to unassociated ones (BREAD-DOCTOR). A word of a semantically related pair will activate the other, producing the priming effects. Inspired by their innovation, subsequent lexical priming studies used a lexical decision task in the test phase, in which participants are asked to decide whether a string of CAPITALIZED letters is a word or not in one language and give their responses as quickly as possible. Their reaction times to target and non-target words will be recorded as the evidence to reveal priming effects. Positive effect, often called facilitation, can be found if participants show faster reaction times. This might be because the priming words activated the target words in the mental lexicon. Negative effect, often called interference or inhibition, can be found if the reaction times are slower compared with that of the unprimed conditions. The presence of priming effects might be a piece of evidence to support the shared storage view, whereas the absence of such effects may support the separate view.

3.2 Masked and unmasked priming

A priming task can be either masked or unmasked. The unmasked priming paradigm was first used by Meyer and Schvaneveldt (1971). In an unmasked priming task, the prime is presented for 100ms and is often detectable to participants. The sequence of the task will be listed as the following:

prime (100ms)

TARGET (1000ms)

It is argued by Kroll (1993) that unmasked priming is likely to trigger strategic allocation of attention to specific parts. In other words, if participants detect the rules of the relation between the related pairs in the priming experiments, they may rely on such a strategy to speed up their responses (Neely, Keefe and Ross, 1989). Therefore, to minimize such attention in priming, masked priming has been employed.

Within a masked lexical decision task, on the other hand, the prime and the target are presented with a mask, usually a row of hash marks, about 50-60ms (Forster, 1998, p.204). Short stimulus onset asynchrony (SOA) is found in masked priming. SOA is the time between the presentation of the prime and the TARGET. In other words, it is the time for a prime to be seen on the screen. However, a short SOA may lead to the invisibility of the prime. The sequence of the masked priming task will be shown as follows:

mask ##### (500ms)

prime stimuli (50ms)

mask ##### (500ms)

TARGET STIMULI (500ms)

This priming paradigm aims to find out whether short exposure to the prime will affect the speed of processing (Foster, 1998). Although the prime in the masked condition can be readable to some participants, it has been argued that the prime is often invisible for most participants as the prime is sandwiched in the middle of two masks.

3.3 Cross-linguistic priming paradigm

The cross-linguistic priming version of lexical decision tasks aim at studying the interaction of two languages during bilingual language processing. The tasks normally use the cross-language word pairs, for instance, semantically related ones or translation equivalents, with a set of words in one language presented in the priming phase, and another set of words in another language in the test phase, for instance, primed words in the first language and lexical decision in the second language, or vice versa.

To investigate whether bilinguals' mental lexicon has a shared or separate conceptual storage, cross-linguistic semantic priming experiments have been adopted. For example, De Groot and Nas (1991) examined Dutch-English bilingual lexicon by comparing the within- and between- language associative priming effects. Both masked and unmasked conditions were used. In experiments 1 and 2, only cognates, the words that are similar in sounds and spelling, were used as the stimuli. In experiments 3 and 4, both cognates and noncognates were adopted. Their findings of cross-language associative priming for cognates, such as *rose–roos*, but not for non-cognates, like *bird–vogel*, suggests that there is a shared conceptual representation for cognates but not for noncognates. This could also be due to frequency effects or activation of competitors. Cognates draw support from both meaning and form relations.

Chen, Zhou, Gao, and Dunlap (2014) conducted three lexical decision experiments to test cross-linguistic translation priming effects with Chinese-English unbalanced bilinguals. The priming tasks were implemented in both L1-L2 and L2-L1 directions. The translation priming effects were only found in the L1-L2 direction, but not in the L2-L1 direction. To put it another way, the priming effects were only found when primed in participants' stronger language. The cross-linguistic priming asymmetry might offer evidence for the Revised Hierarchical Model that there is a common conceptual representation for two languages at the conceptual level, with a separate lexical representation for each language. The asymmetry can also be explained by the BIA+ model that, in visual word recognition, orthographic representations are activated before associated phonological and semantic representation. Besides, the activation of semantic representations is dependent on L2 proficiency. In their (ibid.) study, participants were unbalanced bilinguals with Chinese as the dominant language and English as the weaker one. Thus, the activation of English semantic representations may be slower than that for Chinese characters, which results in the cross-linguistic priming asymmetry.

The effects of different scripts on visual word recognition have been tested cross-linguistically. Gollan, Forster and Frost (1997) tested Hebrew-English bilinguals through the comparison between form-related and unrelated translation primes using lexical decision tasks. Generally, they found stronger priming effects for cognates than for noncognates, and weaker translation priming effects in L2-L1 direction. Their results showed that orthographic differences could be the cue for lexical access in bilinguals' mental structure, which further supports the view of the direct lexical-based or form-based connections between two languages.

A similar study has been done by Kim and Davis (2013) through the examination of Korean-English unbalanced bilinguals. Three different tasks were involved: lexical decision, word naming, and semantic classification. Four groups of word pairs were tested: cognate translations (words sharing phonology and semantics), noncognate translations (words sharing semantics only), homophones (words sharing phonology only) and words sharing neither phonology nor semantics. Significant priming effects were found for both cognates and noncognate translations despite different scripts. However, their study did not show a significant difference between the size of the cognate and noncognate priming effects, which is inconsistent with the results presented in the former study (Gollan et al. 1997). Besides, no phonological priming effects were demonstrated by the lexical decision task in their study. The naming task, on the other hand, showed a robust phonological priming effect, indicating the simultaneous activation of phonological representations from both languages. In their semantic classification task, strong translation priming effects were found but no homophone priming effect was detected. This suggests that access to meaning might not always be through phonological code if two languages are orthographically dissimilar.

In order to know if pure phonological effects can occur during visual word recognition when orthographic and semantic overlaps are absent, Peleg, Degani, Raziq and Taha (2019) examined Arabic-Hebrew bilinguals with Spoken Arabic as their first language and high proficiency in Literal Arabic. All three experiments are based on lexical decision. The stimuli were non-words in either Arabic or Hebrew, as nonwords do not activate semantic representations and do not share orthographic overlaps. In spite of the asymmetric effect from L1 to L2 and from L2 to L1, phonological effects can be obtained between languages that even do not share the same script. The result is consistent with the interactive model proposed by Dijkstra and van Heuven (2002) that, for bilingual, phonological representations in one language can be automatically and non-selectively activated by orthographic representations in the other. What's more, a facilitatory pseudo-homophone effect was found across languages in contrast to the pseudo-homophone interference effect exhibited between languages sharing the same scripts, such as Dutch and English.

3.4 Methods and procedures

Given the methodological background in the previous sections, this part will focus on the design of the experiments in this study by taking into account experimental equipment, participants, stimuli and procedures.

3.4.1 Experimental Equipment and Environment

The same equipment was used for all four experiments. Based on Macintosh, SuperLab 5.5 was used to create and implement experiments, while Cedrus Data Viewer 2.0 was to collect results. The reaction times were collected via a response pad RB-530 which offers 1 millisecond reaction time resolution. The simplicity of such a pad makes it possible even for certain groups of participants, such as children, as it does not require a long time to look for the correct key on the keyboard.

The lab for experiments is a small soundproof room with a chair for participants to sit and a desk on which a computer screen will present stimuli as well as a response pad to collect answers. There is a small window at the back of the lab, enabling the experimenter to monitor the proceedings of the experiments without interfering with the participants. Participants will be left alone in the lab during the whole process to limit the distractions.

3.4.2 Participants

Although participation is voluntary, all participants will be given a free cup of coffee from Starbucks as compensation as the entire experiment took about 25 minutes in total and they had to come to the lab by public transport.

A number of pre-requisites needed to be met. All participants should not suffer from dyslexia or other reading disabilities. All of them should have a normal reading speed and a normal, or corrected to normal, eye-sight. For all experiments, Chinese should be their dominant language (L1) with English as their second language and Norwegian as the third. They have lived in Norway for over four years and have passed both Norwegian and English proficiency tests.

All participants are requested to fill out a questionnaire regarding age, gender, educational background, how many years they lived in Norway and how long they have learned and used English; how long they have learned Norwegian and used Norwegian; whether they learned Norwegian through English instructions; whether they passed English and Norwegian language proficiency tests; and if they can speak other languages in addition to the ones used in the experiments. They were also asked to do a self-evaluation on Chinese, English and Norwegian respectively by indicating their listening, speaking, reading and writing proficiency on a scale from 1 to 6 (see Appendix A).

3.4.3 Experimental stimuli

Altogether 80 word-pairs were used in four experiments, with 40 in Norwegian-Chinese pairs and 40 English-Chinese pairs. As the aim of the experiments was to examine the relationship between form-related and meaning-related word pairs between Norwegian and Chinese, as well as English and Chinese, the word-pairs were divided into four categories:

Cognates (+meaning, +form)

False friends (-meaning, +form)

Translations (+meaning, -form)

Unrelated (-meaning. -form)

Each of the categories consists of 10 word-pairs. The definitions of the four categories will be discussed in detail in the following sections.

3.4.3.1 Cognates

The definitions of the term vary from study to study. In terms of Lemhöfer and Dijkstra (2004), cognates are words identical in orthography and meaning in two languages, such as the English words taxi and hotel which completely overlap with TAXI and HOTEL in Dutch. However, Sáchez-Casas et al. (1992) defined cognates as words sharing a common original stem with a large amount of form and meaning overlap, which is also called non-identical cognates, for example, the English word *rich* and Spanish word *rico*.

Due to the typological differences between Chinese and Norwegian, as well as Chinese between English, there are no one-to-one cognate equivalents that can be found between these language groups. Therefore, word pairs used in this study classified as cognates are similar in sounds and share the same meaning, although different in orthography. For example, *karri* and 咖喱 *ga1 li* were chosen as cognate pairs between Norwegian and Chinese in this experiment.

3.4.3.2 False friends

False friends, also known as lookalikes or interlingual homographs, are defined as identical in spelling but not in meaning, such as the Dutch word *die* meaning «those» whereas the English *die* meaning «to die» (Lemhöfer and Dijkstra, 2004). However, it is never easy to find out words with the same orthography from languages belonging to two different families. Thus, false friends, or sound-alike, in the current study refer to words with similar sounds but not sharing the same orthography or meaning. For instance, *modig* in Norwegian means brave while its sound-alike 目的 *mu4 di4* means «aim» in Chinese. The false-friend word-pairs in this study are matched for the number of syllables and frequency.

3.4.3.3 Translations

Unlike cognates where both orthographic form and meaning are the same or similar, translations in this study are words that do not share the same or similar pronunciation, but share the same, or similar, meaning. However, some problems arise. A word in one language may have several translations in another. For instance, 银行 *yin2 hang2*, in Chinese can be translated to *a bank* in English, while the English word bank can mean 银行 *yin2 hang2* and 岸 *an4* in Chinese. The former in Chinese means an organization that provides financial services, while the latter means the side of a river. As a result, to avoid confusion, this kind of word has been excluded from this study. Words with a one-to-one correlation between Chinese and Norwegian as well as Chinese and English are selected.

3.4.3.4 Unrelated

Neither form nor meaning similarities can be found between the unrelated word pairs. Besides, this category of words shares no semantic relations in two languages. An example of an unrelated word pair taken from one of the experiments is the Norwegian-Chinese word pair *navn* and 森林 *sen1 lin2*, meaning name and forest respectively, which share no resemblance in orthography and meaning.

3.4.3.5 Non-words

A non-word ratio of 50/50 has been suggested by Altarriba and Basnight-Brown (2007) to avoid bias in one direction or another in lexical experiments. Therefore, to supplement 40 Norwegian-Chinese word pairs and 40 English-Chinese word pairs, altogether 160 non-words were created, with 40 for Norwegian, 40 for English and 80 for Chinese.

All Norwegian and English non-words are made up following the basic syllable structure in these two languages and were double-checked by Norwegian native speakers and English native speakers to ensure the feasibility of those non-words. Due to the special formation rules of Chinese characters, non-words in Mandarin Chinese were created by a random combination of two or three pseudo-characters and/or non-characters, ensuring that all the nonwords lack a dictionary meaning, and lack any agreed pronunciation. The pseudo-characters and non-characters were created according to the following rules:

Rule 1: reducing the strokes

尢 is from 尤 *you2*，and 珏 is from 琴 *qin2*

Rule 2: the combination of two correct characters

云云 is a combination of 云 *yun2* and 云 *yun2*

Rule 3: non-characters with correct stroke pattern positioning

忄国 is from the radical 忄 and 国 *guo2*

Rule 4: illegal stroke pattern positioning

者纟 is from 绪 *xu4*

All these examples are taken from the experiments 1-4. The made-up Chinese non-words were double-checked by a native speaker of Cantonese to make sure those non-words are not words in Cantonese as well.

3.4.4 Experimental design

The experiment was divided into three blocks: an introduction block, an experimental block, and an end block. In the introduction block, instructions regarding how to do the lexical decision task were explained. The experimental block follows the instruction block, within which experiments 1-4 are all included, each with an individual introduction preceding them. The end block tells participants this is the end of the experiment. The training was designed the same as the experiment (three blocks: an introduction, training and an end) but separate from the real experiment. A separate training session was designed to ensure all the participants were fully aware of the instructions and the whole process of the experiment. During the training, participants were required to give yes or no answers to a set of words and non-words by pressing the green button or red button respectively. There were 8 trials in the training block: 4 tests and 4 instructions. After each test, participants will be informed of what will be presented next and what they are required to do next. When being presented with the instruction, they were told to press any button to continue at their own pace. The experimental block follows the same pattern as the training block.

Both the training and the experiments 1-4 follow the priming sequence illustrated below, in which a fixation mark '*' was visible for 100ms, followed by a forward mask made up of hash marks '########' for 75ms. After that, the prime was presented in lower case letters for 50ms, which was followed by a backward mask identical to the forward one for 75ms. Then the target was visible at last for up to 1000ms or until a response was given.

The unprimed version was presented together with the primed experiments, differing only with respect to the primes. The unprimed baseline showed an empty screen for 50ms. Thus, no lexical pre-activation of either competition or targets was possible. See below.

Priming sequence for experiments 1-4:

* (75ms)

######## (75ms)

prime (50ms)

######## (75ms)

TARGET (1000ms)

Sequence for unprimed baseline in experiments 1-4:

* (75ms)

######## (75ms)

######## (75ms)

TARGET (1000ms)

Experiments 1-4

Experiments 1 and 2 were composed of 40 Norwegian-Chinese word pairs, matched with 80 non-words. Experiments 3 and 4 consisted of 40 English-Chinese word pairs together with 80 non-words.

In experiment 1, subjects were primed in Norwegian and were asked to decide whether the characters on the screen were real words in Mandarin Chinese. Experiment 2 was different from experiment 1 in the direction, which was primed in Mandarin Chinese and doing the decision task in Norwegian. Participants were asked to focus on capitalized letters and decide if the letter strings were real words in Norwegian. Experiment 3 examined the priming effects between English and Chinese, where 10 English words in each category were primed and the same number of Chinese targets were given. The difference between experiments 4 and 3 only lies in the direction of primes and targets. A string of upper-case letters was presented to participants and they were asked to answer yes if they think it was an English word or no if it was not. To avoid repetition effects, half of the participants were asked to do the Norwegian to Chinese direction or English to Chinese direction first, while the other half were presented with the Chinese to Norwegian or Chinese to English direction first.

3.4.5 Experimental procedure

Before entering the lab, participants were asked to fill out a questionnaire in English mentioned above. Each participant was tested individually in a quiet room in a session that lasted approximately 25 minutes. The entire experiment was conducted in English. The instructions in English would be presented on the screen and participants were allowed to read through them at their own speed until they fully understood the tasks. After that, participants were asked to press any key on the response pad to start the experiment.

There was a separate training session consisting of 8 prime-TARGET pairs which were designed the same as those in the four experiments. The idea of a separate training test was to help participants get a whole picture of what they were going to do in the real experiments and to adapt themselves to the pace of the tasks as most of them came to the lab after a day's work. During the training, participants could ask the experimenter if anything was unclear. After the 8 training word pairs, participants were informed to start the experiment whenever they feel confident and comfortable. The experimenter would wait outside the experiment room at all times.

Chapter 4 Results

The current research aims at revealing form and meaning relations between Chinese and Norwegian as well as Chinese and English. Four lexical decision tasks were conducted with Experiment 1 from Norwegian (L3) to Chinese (L1), Experiment 2 from L1 to L3, Experiment 3 from English (L2) to Chinese (L1) and Experiment 4 from L1 to L2.

The following sections will present the results of experiments 1-4 respectively. All four experiments were lexical decision tasks based on the priming paradigm across languages. Specifically, experiments 1 and 2 tested the interaction between Norwegian and Chinese, which will be described in sections 4.1 and 4.2, whereas experiments 3 and 4 examined the relationship between English and Chinese, see details in section 4.3 and 4.4. Section 4.5 will give an overview of the decision for nonwords among these three languages.

4.1 An Overview of participants

A total number of 20 Chinese, 15 females and 5 males, were recruited for experiments 1 to 4. All participants were native speakers of Chinese and aged between 24 and 45. They all have lived in Norway for over four years. All of them have learned English as their second language and Norwegian as the third. 15 of them reported English as the language that they would use in their working/studying environment, while Norwegian in their daily use. The other 5 participants indicated both Norwegian and English as the language in their working or studying environment. They all have learned Norwegian bokmål under English instructions after coming to Norway. According to their selfreports, they all had taken the English Proficiency test (IELTS) with the overall mean score 6, which is equal to B2 and above, and passed the Norwegian proficiency test with B1 level. Participation was voluntary and free coffee was provided as a sign of appreciation. More detail of the participants is given in Table 4.1 below.

Age group	Female	Male
18-25	5	0
25-35	7	5
35-45	3	0

Table 4.1 Age group of participants

The average age of female participants is 30.27, whereas that of male participants is 32.6. The average age at which participants started to learn English as their second language is 10.35, whereas that of Norwegian is 23.15. The average years of using English is 12.5, while that of Norwegian is 6.6.

4.2 Word length and complexity

In all four experiments, 5 Chinese words were three-character compounds and the rest of the Chinese stimuli were all two-character compounds. The complexity was based on the number of strokes. The length of an English word or a Norwegian word was calculated according to its syllable number. Chinese words had an average of 15.35 strokes in English-Chinese experiments and 17.62 strokes in Norwegian-Chinese experiments. The English words on average consisted of 1.9 syllables and the Norwegian words of 1.82 syllables.

For the nonword groups, to match the real word pairs, 5 nonwords were made up of three pseudo-characters and/or non-characters, with an average of 15.61 strokes, for Chinese conditions. The English and Norwegian nonwords were also calculated based on the number of syllables, with an average of 2.45 syllables for English nonwords and of 2 for Norwegian respectively.

4.3 Overall reaction times by each direction

To measure the effects of lexicality (word vs. nonword), form and meaning relations on the lexical decision, accuracy scores and reaction times of participants were collected and analyzed using the lme4 package in R.

Overall, 20 participants produced 9490 correct responses out of 12800 counts, of which less correct answers were produced from Chinese to either English or Norwegian. After excluding the outliers who were less correct, the correct response rate increased from 74.14% to 76%. Half of them were presented with the sequence from Norwegian-Chinese and Chinese-Norwegian first to English-Chinese and Chinese-English at last, while the other half were tested with the reverse sequence, from Chinese-English to Norwegian-Chinese. Three participants (3, 8, 10) were excluded from the analysis due to their less correct rate. Subject 3 chose more wrong alternatives, 8 and 10 failed to respond (NR) in time. See figure 4.1 for more detail.

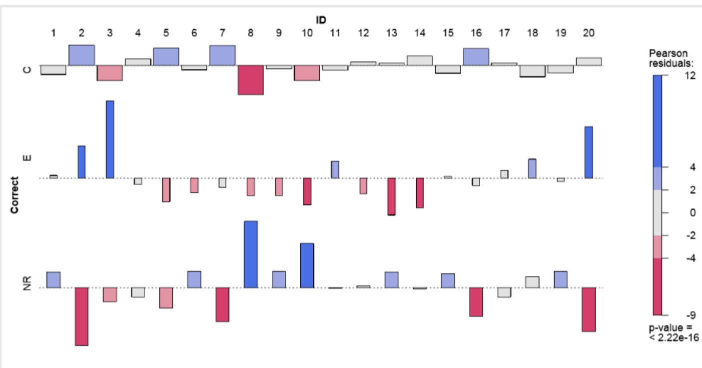

Figure 4.1 Outliers with less correct rate

	Mean RT for correct answers (ms)	Error rate (%)
English to Chinese	651.13	1.56
Norwegian to Chinese	661.43	1.16
Chinese to English	799.19	9.19
Chinese to Norwegian	802.82	12.66

Table 4.2 Mean reaction times for correct answers and error rate of each direction

Taking into account language differences, the decisions for Chinese characters are always faster, whereas the decisions for alphabetic scripts are slower (see Table 4.2). There is a meaning advantage that translation and cognates are faster to decide when primed before. However, false friends and unrelated items show longer reaction times. Table 4.2 also revealed that participants tended to make more errors in English (L2) and Norwegian (L3) targets than Chinese (L1) targets.

4.3 Experiment 1 Chinese Target Lexical Decision Task primed by Norwegian

Experiment 1 was a one direction task with Norwegian words as primes and lexical decision on Chinese target words and non-words. Stimuli in this experiment consisted of 40 word-pairs (Norwegian primes-Chinese targets) and another 40 Norwegian nonword primes-Chinese nonword targets pairs. All Norwegian primes appeared in lower case and all Chinese targets were created by using the Windows 3D Picture in Kai fonts, presented in black at the center of the picture against a white background.

Reaction times for all targets were collected. Only correct answers were considered in the analysis of reaction times. The ANOVA test of repeated measures of reaction time revealed that no significant priming effects for either form [F (1, 23.43) =0.03, p = 0.87] or meaning relations [F (1, 24.92) =0.03, p = 0.86] when primed by Norwegian words while doing lexical decisions on Chinese targets. The small decreasing tendency for the *Yes* line in figure 4.2 after being primed is not significant. The same is found in figure 4.3 where the line named *Yes* saw a slight decrease. No significant priming was found from Norwegian to Chinese.

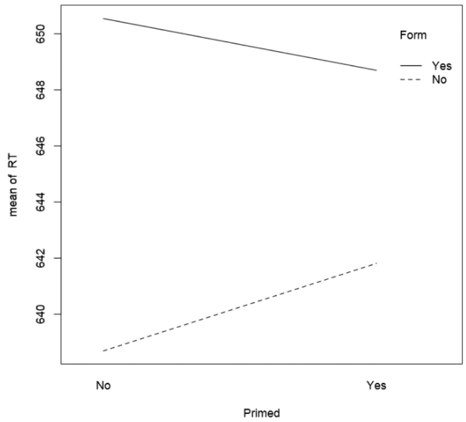

Figure 4.2 An overview of the reaction times for the inside participants by form from Norwegian to Chinese

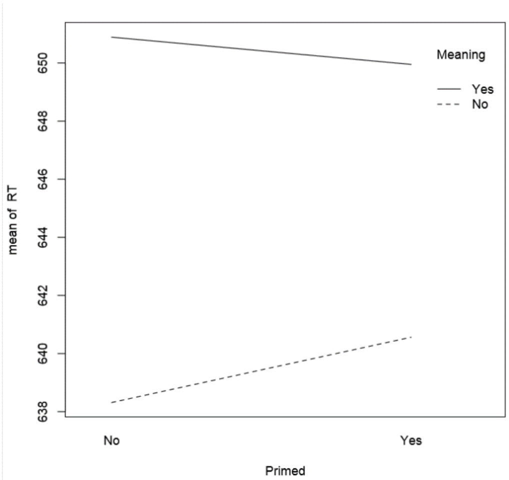

Figure 4.3 An overview of the reaction times for the inside participants by meaning from Norwegian to Chinese

4.4 Experiment 2 Norwegian target lexical decision task primed by Chinese

The same group of participants in experiment 1 also took part in experiment 2. Experiment 2 was the reverse direction of experiment 1 with Chinese words as primes and Norwegian as targets. The stimuli list used in experiment 2 was identical to that of experiment 1 and the procedure was the same as that of experiment 1. However, the Norwegian targets were presented in upper case letters.

Only correct answers were included in the analysis of reaction times. The Type III ANOVA in R did not show interaction between form and priming, but priming is confirmed [F (1,27.8) = 8.56, p = 0.0068] (see figure 4.4 below), whereas the significant priming effects can be found for meaning and primes between Chinese and Norwegian word pairs [F (1, 25.7) =7.44, p = 0.011] (see figure 4.5 below).

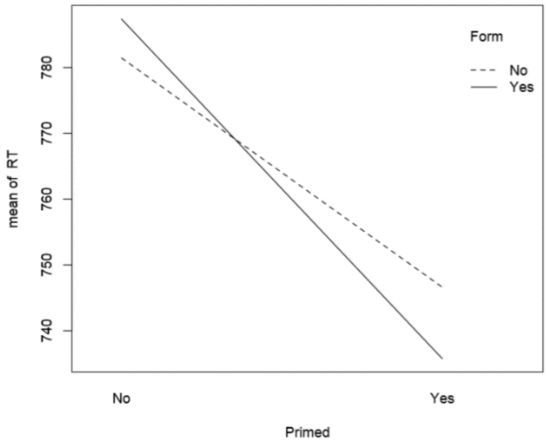

Figure 4.4 The interaction plot of primed and unprimed form-related word pairs between Norwegian and Chinese

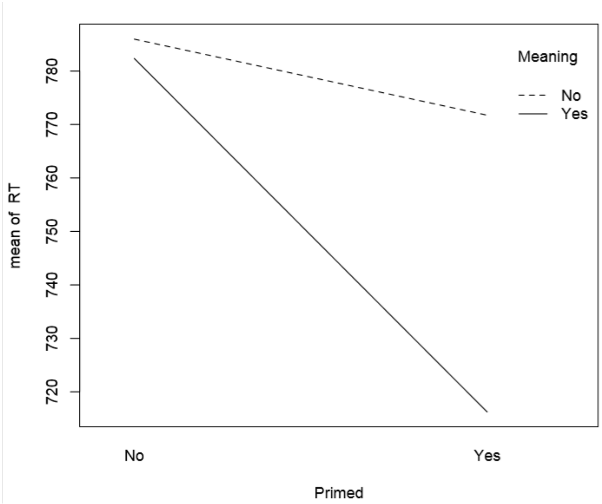

Figure 4.5 The interaction plot of primed and unprimed meaning-related word pairs between Norwegian and Chinese

4.5 Experiment 3 Chinese target lexical decision primed by English words

The same group of participants in experiments 1 and 2 took part in experiment 3. Experiment 3 was identical to experiment 1 in a structure that all primes were presented in lower case letters and all Chinese targets were presented in black and in Kai font against the white background at the center of the picture. Different from experiment 1, all primes in experiment 3 were English and all targets were Chinese words and nonwords.

Only correct answers were included in the analysis of reaction times. An ANOVA test of repeated measures shows priming effects (but not significant) for both form [F (1,17.5) =5.65, p=0.029] (figure 4.6) and meaning-related word pairs [F (1,19.5) =5.23, p = 0.033] (figure 4.7).

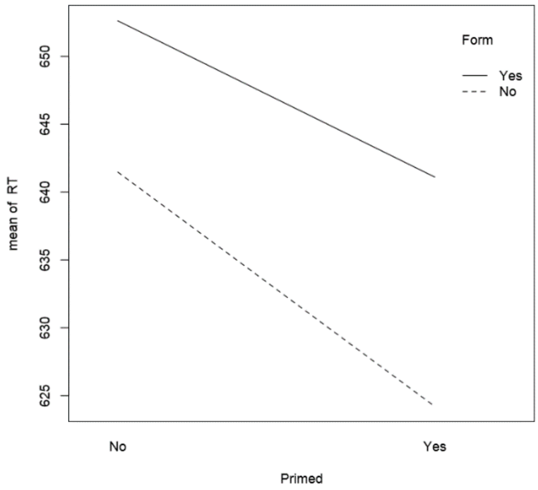

Figure 4.6 The interaction plot of primed and unprimed form-related word pairs between English and Chinese

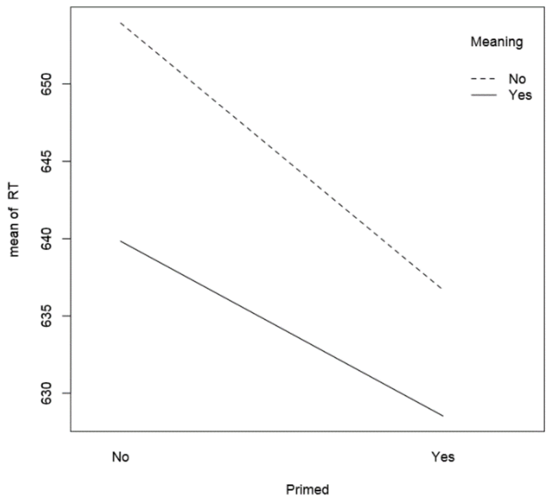

Figure 4.7 The interaction plot of primed and unprimed meaning-related word pairs between English and Chinese

4.6 Experiment 4 English targets lexical decision tasks primed by Chinese words

The same group of participants in experiments 1, 2 and 3 took part in experiment 4. The word list in experiment 4 was identical as in experiment 3 with the reverse direction from Chinese primes to English targets. All English targets were presented in capitalized letters. The procedure in this experiment was the same as the former three experiments.

Only correct answers were considered for the analysis of reaction times. An ANOVA test of repeated measures shows a significant priming effect of meaning-related words (translations and cognates) [F(1,65.6)=9.3, p=0.0033], whereas no priming effects were confirmed for form-related counterparts (false friends and cognates) [F(1,71.63)=1.52, p=0.22].

Although the reaction time seems a decrease with 20ms difference for primed and unprimed conditions in figure 4.8, it might be the effects caused by the cognates primes that also share corresponding meanings with the targets.

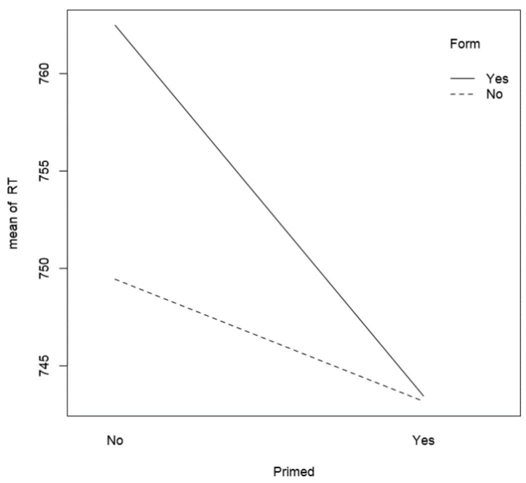

Figure 4.8 The interaction plot of primed and unprimed form-related word pairs between English and Chinese

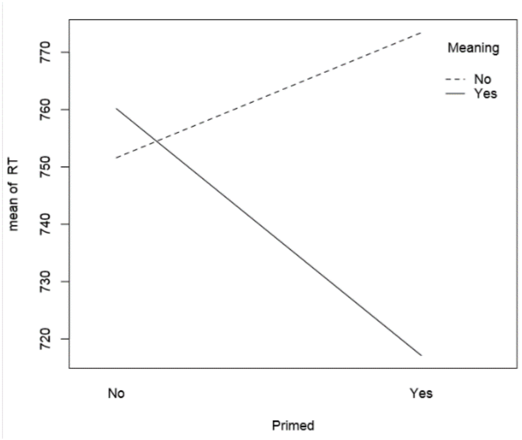

Figure 4.9 The interaction plot of primed and unprimed meaning-related word pairs between English and Chinese

As can be seen from figure 4.9, the meaning relations between Chinese primes and English targets are very significant, with a faster reaction time (>40ms) compared with the unprimed condition.

4.7 Results for nonwords

Only the correct recognitions of nonwords were considered for analysis of reaction times. As can be seen from figure 4.10, Chinese nonword signs are significantly faster to decide compared with an alphabetic string of letters. It might be easier for participants to make a decision. However, as shown in table 4.3, compared with the number of Chinese signs classified as nonwords (with accuracy rate 94.06% from English to Chinese and 96.12% from Norwegian to Chinese respectively), the number of the correctly recognized alphabetic string of letters (with the accuracy rate 36% for English and only 29.81% for Norwegian respectively) demonstrated the difficulty for participants to make decisions. More discussions see Chapter 5.5 Nonwords.

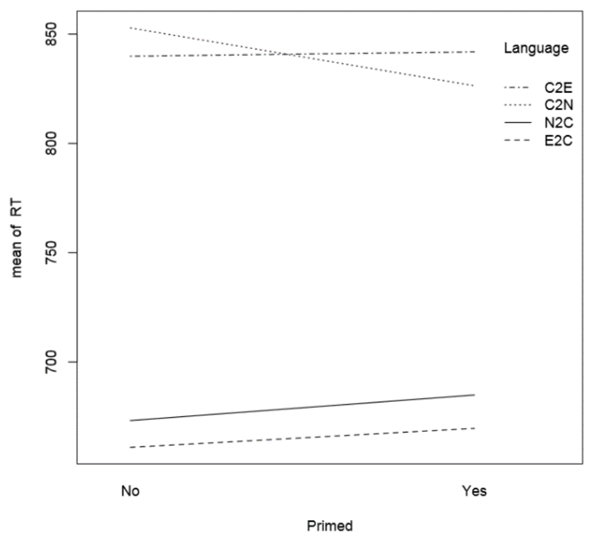

Figure 4.10 Mean reaction times for nonwords in four experiments

Direction	Number of correct decisions	Number of expected decisions
Chinese to English	576	1600
Chinese to Norwegian	477	1600
English to Chinese	1505	1600
Norwegian to Chinese	1538	1600

Table 4.3 The number of items correctly decided as nonwords in each experiment

4.8 Summary

To wrap it up, the priming effects found among these three languages are asymmetric. Specifically, when primed from Chinese to either English or Norwegian, there is a meaning advantage, that is, both cognate and translation word pairs see a faster reaction time. For two alphabetic languages, form priming effects were only detected from English to Chinese direction but not from Norwegian to Chinese. This could be a proficiency effect (see more discussions in chapter 5). Neither form nor meaning priming effects have been found from Norwegian (L3) to Chinese (L1).

Nonwords seem a difficult problem to handle. Chinese nonwords are faster to decide and with a higher accuracy rate, whereas Norwegian and English nonwords are more difficult for participants to make a decision and with a lower accuracy rate due to a much higher incorrect rate. This contradicts the Word Superiority Effect (Paap et al., 1982), which suggested that in alphabetic languages words are typically faster to recognize.

Chapter 5 Discussion

In a nutshell, by using a cross-linguistic priming paradigm, the present study examined the meaning and form relations between one's L1 and L2, as well as L1 and L3 to find out how three languages are interacting with each other. Priming effects were found for meaning related words across languages. Besides, a number of patterns were observed consistent with previous findings, such as priming asymmetry (section 5.3). The following sections will give detailed interpretations of the previously presented findings by comparing meaning (section 5.1) and form aspects (section 5.2) based on the models discussed in chapter two. The recognition of nonwords (section 5.5) will be discussed in detail as this may support the assumption that reading alphabetic languages and logographic languages involve different routes, and reading Chinese may not be through phonology. The chapter will end up with suggestions for future research (section 5.6).

5.1 Meaning Advantage

The findings of this study show an advantage for meaning related words for L1-L2 (Chinese to English), L2-L1 (English to Chinese) and L1-L3 (Chinese to Norwegian) lexical decision tasks. According to Lemhöfer and Dijkstra (2004), see also Dijkstra and Van Hell (2002), homographic cognates are processed faster in L2 lexical decision tasks. L1 targets were found faster reaction times when primed by either L1 or L3 cognates. Although cognates in this study did not show orthographic closeness, the meaning related words (i.e. cognates and translations) were recognized faster than the unrelated counterparts (i.e. form related and unrelated words) in these three conditions.

This is consistent with previous findings between Chinese and English that translation facilitation in lexical decision tasks (e.g. Chen & Ng, 1989; Jiang & Forster, 2001) and in agreement with the Revised Hierarchical Model (RHM, Kroll & Stewart, 1994) in that meaning would be the link for bilinguals' mental lexicon of two languages.

However, experiment 1 (Norwegian to Chinese) shows neither meaning nor form priming effects as compared with English to Chinese condition. This is probably because users' experience of Norwegian is less than that of English. In other words, the participants' Norwegian are less proficient than their English. In terms of a neural network model, DevLex-II, introduced by Zhao and Li (2010), bilinguals' mental representations of two languages are highly associated with their language learning history. Their simulation suggested that the onset time of learning a new language is highly correlated with the structure of mental representations. In other words, words from a new language were distributed in small chunks depending on the meaning similarity between the new one and the well-organized L1. In the current study, all participants have learned Norwegian at a relatively late age in contrast to their acquisition of English and still in the process of becoming more proficient.

Moreover, lexical items in Norwegian are represented in more dense neighborhoods and thus resulting in increased lexical competition from their nearby neighbors (more will be discussed in section 5.5 by the higher error rate for recognizing L2 and L3 nonwords in experiment 2 and 4). As a result, a very brief exposure to the Norwegian primes may not trigger activations to spread to the corresponding targets in Chinese. This may imply that the mental representations of late Norwegian learners in this study may be relatively poor in contrast to the better organization of their L2 English and L1 Chinese. On the other hand, L1 primes are strong enough to spread activation to L3 targets as they have less competition and more associations in participants' mental lexicon, which is also the case for experiment 4 where Chinese served as primes and English as targets.

For experiment 3 (English to Chinese), as the proficiency of participants' English is higher than that of their Norwegian, their mental representations of English may be more organized. In other words, the conceptual link between English and the corresponding concepts are clearer than that of Norwegian counterparts in their mental lexicon, leading to the priming effects from English to Chinese rather than from Norwegian to Chinese if the primes and targets are meaning-related.

Overall, the priming effects found for meaning-related word pairs across languages in the present study indicate that meaning might be a reliable link for multilingual from a logographic language to alphabetic languages. Besides, no priming effects observed from Norwegian to Chinese suggests that the link between Norwegian and related concepts are less clear due to their relatively lower proficiency in contrast to English. However, at least, English words and Chinese equivalents might be connected through a shared conceptual representation. Because if connections between lexical items in L1 and corresponding concepts are strong, whereas such connections between lexical items in L2 and related concepts are weak, priming effects can only be found from L1 to L2, but not the other direction. This is not the case in this study.

5.2 Form-related priming effects

In contrast to meaning related words, form related counterparts did not see significant priming effects across languages, which is in line with the study by Dijkstra et al. (1998) that no difference in response times for interlingual homographs (Dutch-English) and matched controls.

The only slightly observed effects might result from cognates who share not only form but also meaning relations between targets and primes. No significant form priming effects, in turn, supports that meaning is the reliable link for Chinese to access alphabetic languages. The only significant form priming effects were found in

Experiment 3, from English primes to Chinese targets. One possible explanation might be that, on average, participants have learned English since their secondary school and used their second language for over 10 years and all learned Norwegian under English instructions. It is probably due to their relatively higher proficiency in English and the frequency of English words encountered that makes the English primes in the current study more accessible.

Besides, the Chinese phonological system, Pinyin, might play a part in assisting the process of form-related word pairs. To be specific, the phonological skills in learning Pinyin can be transferred to an alphabetic language. Some studies (e.g. Chien et al., 2008; Chow, 2014) revealed that Chinese phonological awareness, such as phoneme segmentation and deletion acquired in learning Chinese can be transferrable to English. During the initial stages of learning English, to learn how to pronounce the alphabetic words, Chinese speakers were getting used to writing down the Pinyin form which has a similar pronunciation to an English word, just as what they did in order to learn a new character of Chinese. However, when learning Norwegian, as all of them were under English instructions instead of their native one, the awareness acquired in Chinese may not play a part in assisting in learning their L3. However, whether the form priming effects found in this direction but not from Norwegian to Chinese is due to the proficiency of participants or the learning process of Chinese native speakers regarding English or even the mechanism of the experiment needs further research. Moreover, whether the phonological awareness obtained from English could be transferred to Norwegian is still unknown and needs further testing.

5.3 Asymmetric effects

The priming effects found in the current study are asymmetric. Specifically, significant priming effects were found for meaning-related word pairs from Chinese to English and vice versa, whereas such effects were found from Chinese to Norwegian only. As for form-related word pairs, priming effects were only found from L2 to L1 (English to Chinese). No reliable priming effects were found for the other three directions.

The asymmetry is the key assumption of Kroll and Stewart's Revised Hierarchy Model (1994), in which lexical links from L2 to L1 are stronger due to the translations from L2 to L1. When bilinguals' proficiency in L2 gradually increases, the priming asymmetry will become less salient. In the present study, participants' L3 (Norwegian) is less proficient, they rely much on translations, resulting in stronger lexical links between Norwegian and Chinese.

As for asymmetric effects found for form-related word pairs, one possible reason could be that when the Chinese primes occur, an additional step is to find the corresponding phonological information in the cognitive network (Tan et al., 2005) before matching the L2 equivalents. The additional time in processing the Chinese primes results in the delay in recognizing the targets.

5.4 Masked versus unmasked priming

Whether the mask inhibits or facilitates the activation of the target has received much debate. It is argued that L2-L1 priming can be achieved if the L2 primes are not masked (Jin, 1990; Chen & Ng, 1989; Frenck & Pynte, 1987). In other words, if the primes can be observable by participants, the activation of L1 words can be followed. In the case of meaning-related word pairs in this study, masks did not inhibit the recognition of L1 targets primed by L2 words as both directions demonstrated significant priming effects. However, further testing is necessary to see whether no meaning priming effects in L3-L1 direction is the consequence of masks or a matter of participants' proficiency.

For the form-related word pairs, it is also argued by Forster (1987, 1998) that form priming effects can only become significant by using the masks based on the entry-opening model (Forster & Davis, 1984). According to the model, priming occurs when the prime opens the entry for the target, which produces a savings effect for the recognition of the target as the evaluation process has already initiated by the time the target being presented. This is not the case for nonidentical primes and targets, where a further evaluation of the prime is required. If the prime does not finish the evaluation process, no target words could be matched. The masks will provide more opportunities for the unsuccessful candidates before the entry closes down. To test this hypothesis, Forster et al. (1987) did find form priming effects for graphemically similar prime-target pairs within a masked priming paradigm. However, the stimulus onset asynchrony (SOA) used in their study was 60ms, whereas, in the present study, the SOA is 100ms which is long enough for meaning to be activated. Thus, the form priming effects found in English-to-Chinese direction cannot be accounted for by this hypothesis, because if such an assumption is at play, the same effects could be expected in the reverse direction (Chinese to English) as well. No form priming has been found here.

5.5 Discussion for Nonwords

The most surprising and interesting results in this study may come from the response times and accuracy rate for nonwords decisions. Neither English nor Norwegian witnessed a high accuracy rate and shorter response time in rejecting nonwords, whereas rejecting nonwords of characters seems much easier and less demanding.

To account for the observed facts, orthographic neighborhood density might be one of the reasons why Chinese participants responded to alphabetic nonwords less accurately and slowly. Being defined by Coltheart et al. (1977), it refers to the number of phonologically similar words in the lexicon and is most often created by changing, adding, deleting, or substituting a single letter in a given word. For example, the word 'hit' has more neighbors (e.g. sit, it, split) than the word 'calculate'. Neighbors are items that are highly confusable with the target word, in the sense that they share a large number of features with the target. Words with more neighbors are said to be in dense neighborhoods, whereas words with fewer neighbors are in sparse neighborhoods. It is plausible that words with more neighbors require longer to be processed due to the competition, whereas it takes a relatively shorter time to recognize words with fewer neighbors. The English and Norwegian nonwords, or more precisely pseudowords, created in this study all followed the word-formation rules by substituting, changing a single sound or some letters. The pronounceable pseudowords increased the competition among other possible targets, making them difficult to discriminate from the original words for nonnative speakers. Therefore, rejecting the pseudowords might be time-consuming (e.g. more than 1000ms needed).

Another possible explanation could be the recognition of alphabetic string of letters depending on phonological awareness, whereas the recognition of logographic signs depending on orthographic awareness. However, readers with a nonalphabetic L1 rely less on phonological information to read English words (Wang & Geva, 2003; Wang, Koda, & Perfetti, 2003). Phonological awareness in alphabetic languages mainly refers to the awareness of the sound structure of a language, which allows one to discriminate and manipulate the sounds at different levels, such as words, syllables. For instance, a typical phonological task involves the identification of words sharing the same rhyme, such as *cat* and *mat*. Durgunoglu et al. (1993) suggested that phonological awareness in one is highly correlated with the phonological skills in the other. In their (ibid.) study, Spanish-English bilinguals showed that those who performed better in Spanish phonological awareness tasks were also better in reading English words and pseudowords.

On the other hand, orthographic awareness, or orthographic knowledge refers to the ability to form, store and access orthographic representations (Burt, 2006). It is argued by researchers (Peng, Li, & Yang, 1997; Taft et al., 1999; Wang, Perfetti, & Liu, 2005) that orthographic awareness regarding the radicals and their positional information is the basic process in reading Chinese characters, which does not only represent in native speakers' lexicon but also in the mental lexicon of learners of Chinese. Also, studies by Wang, Perfetti and Liu (2005) revealed that orthographic awareness is the predictor of Chinese reading and such kinds of skills do not predict English pseudowords reading. To put it another way, what the participants have obtained in acquiring their native logographic Chinese does not guarantee their discrimination of alphabetic pseudowords.

Talking about the Chinese characters, semantic-phonetic compound characters account for approximately 72% of the whole character inventory. Of these characters, 27% of radicals have fixed positions and 43% radicals can appear in more than one position (Shu et al., 2003). Orthographic awareness requires learners of Chinese to be aware of the radical positions. 90% of nonwords in this study were composed of illegal characters with radicals in an illegal position, making it possible for native speakers to observe the irregularity of the made-up words due to their implicit orthographic knowledge through enough exposure of characters.

Also, fast reaction times in rejecting illegal characters may provide evidence that recognizing Chinese characters does not always require phonological information at least for highly proficient speakers. In other words, the recognition of radical combination may not spread the activation (Dell, 1986) of phonological information regarding pseudowords in mental lexicon as the illegal position of the radicals makes pseudo-characters unpronounceable.

Third, reading Chinese characters requires orthography-to-phonology transformation, a direct retrieval of phonological information from the cognitive network, whereas reading alphabetic languages requires grapheme-to-phoneme conversion (Tan et al. 2005). Nonwords of Chinese in this study are composed of two to three characters and one Chinese character is mapped to one syllable. If this criterion applies to recognizing nonwords of Chinese, then what makes it fast to reject nonwords could be no orthography to phonology transformation available in participants' cognitive network. If this is the case, reading of Chinese characters cannot be achieved without phonology, which further suggests that reading Chinese may be through dual routes.

Evidence can also be found in neuroscience studies. According to the studies on Chinese and English processing by recording the brain activity of participants (Bolger et al., 2005; Huang et al., 2012; Tan et al., 2000), the bilateral fusiform gyri were involved in Chinese reading, while only the left counterparts were found when reading English. Wu et al. (2012) used the activation likelihood estimation method to examine orthographic, phonological and semantic processing of Chinese characters by relevant linguistic tasks while recording the activation pattern by fMRI. The right superior temporal gyrus was identified for phonological processing. Besides, bilateral activation of the ventral occipitotemporal regions was observed for both phonological and semantic processing. Studies (e.g. Siok et al., 2008; Siok et al., 2004; Tan et al., 2000) from dyslexia also support this view. For instance, the brain of dyslexia in Chinese was dedicated to images and shapes, while that for English dyslexia was associated with converting letters to sounds. It is reasonable to assume that rejecting nonwords of characters may involve the process of holistic visual recognition which does not require the engagement of the left hemisphere to deal with specific linguistic features of the characters and thus rejecting nonwords is less time-consuming.

5.6 Further research

As research goes on, there are still some unanswered questions requiring further study. The first one would be to see whether the form priming effects found in Chinese-to-English, not the reverse direction is due to the proficiency of participants or the learning process of Chinese native speakers regarding English. Another one would be interesting to see the interaction between English and Norwegian by conducting corresponding lexical decision tasks. This could make a comparison between the observed more proficient English and less proficient Norwegian and see if proficiency plays a part in triggering priming effects. It will also show whether one's L2 can be transferred to L3 learning.

It would also be interesting to see if unmasked primes will increase the reaction times from the weaker language to the stronger ones, but chances are that participants might be aware of the whole process of the task resulting in a specific strategy in speeding up the reaction time. Another way could be still under the masked priming paradigm, for example, prime being presented with less than 60ms rather than 100ms in this study, to see if form priming effects can be triggered.

The most intriguing one would be to investigate whether the reading of Chinese characters and/or signs is independent of linguistic features by, for instance, adopting the visual stimuli methods such as fast periodic visual stimulation (Lochy et al., 2015, 2016; Ghelcke et al., 2020), combined with the study of brain activation like EEG used in face recognition. Fast Periodic Visual Stimulation refers to the presentation of the stimuli at a fixed rate. Since no explicit behavioral tasks needed, this method could be optimal in solving the problem of unpronounceable pseudo-characters.

Chapter 6 Conclusion

Most previous studies on cross-linguistic priming effects between Chinese and English have focused on the translation equivalents or the semantically related word pairs. In addition to the meaning influence, present study also investigated how form affects the mental process of word recognition of multilinguals (i.e. Chinese native speaker with English as their second language and Norwegian as the third) by using interlingual homograph pairs across languages. A series of lexical decision tasks under the masked priming paradigm was conducted to reveal a robust meaning priming effect across language groups, which is consistent with what has been expected in hypothesis 3. Both cognates and translations were faster to decide than false friends and unrelated word pairs, suggesting that meaning is the reliable link for words from typologically different languages to be connected in the mental lexicon of multilingual.

Asymmetric priming effects might have resulted from the multilingual different proficiency in two alphabetic languages, which is in agreement with previous findings that very brief exposure of the primes in a weaker language may not trigger strong activations to be spread to the targets (e.g. Norwegian to Chinese meaning-related words).

The significant short reaction times on rejecting nonwords of characters in contrast to the longer time of discriminating alphabetic nonwords may indicate the different route of recognizing logographic signs and the alphabetic string of letters. Specifically, the recognition of alphabetic letters requires less orthographic awareness than logographic Chinese does. The strategy used in discriminating nonwords of characters may not be transferrable in rejecting alphabetic nonwords. Besides, recognition of pseudowords made up of pseudo-characters may support that phonological information does not always play a role in Chinese recognition.

However, it is still hard to draw a concrete conclusion whether the recognition of Chinese characters is through phonology based on the findings of the current study. It is difficult to conclude whether the recognition of signs, both words and nonwords, is dependent on the orthographic awareness involved in processing radicals and their positional information or on the phonological information retrieval by using the visual stimuli only in lexical decision tasks. Possibly, reading Chinese is different from listening to Chinese. The former may involve a less linguistic but a more aesthetic approach. It would be possible to use auditory stimuli in a similar experiment to find out more details multi-lingual processing of Chinese in Reading and Listening.

Appendix A

Questionnaire for Lexical Decision Experiments

Participant number:

Age: under 18 18-25 25-35 35-45 45-55 over 55

Gender: Male Female

How many years have you lived in Norway?

What is your educational background (e.g. undergraduate, postgraduate, Phd, etc.)?

What languages do you speak?

How long have you learned English? How often do you use English?

Have you ever attended any English language proficiency tests (e.g. IELTS, TOEFL, etc.)? If yes, what is the score of your test and the score for each subsection (e.g. listening, reading, writing, speaking)?

How long have you learned Norwegian? How often do you use Norwegian?

Have you ever attended any Norwegian language proficiency tests? If yes, what is the level of your test and the level for each subsection (e.g. listening, reading, writing, speaking)?

Self-evaluation: (1-6: 1: entry level 2: beginner 3: intermediate 4: intermediate and advanced 5: advanced 6: proficient)

Your level of your native language:

Listening

Reading

Speaking

Writing

Your level of English:

Listening

Reading

Speaking

Writing

Your level of Norwegian:

Listening

Reading

Speaking

Writing

Appendix B

Stimuli

Norwegian to Chinese:

Cognates

Norwegian words	Chinese characters	Pinyin
blog	博客	bo 2 ke 4
litchi	荔枝	li4 zhi1
tyfon	台风	tai2 feng1
tofu	豆腐	dou4 fu
ballet	芭蕾	ba1 lei2
bikini	比基尼	bi3 ji1 ni2
karri	咖喱	ga1 li
sigar	雪茄	xue3 jia
salat	沙拉	sha1 la1
kaffe	咖啡	ka1 fei1

Sound-alikes

Norwegian words	Chinese characters	Pinyin
modig	目的	mu4 di1
tango	糖果	tang2 guo3
yoghurt	摇滚	yao2 gun3
salon	唢呐	suo3 na4
honning	哄你	hong3 ni3

tanke	坦克	tan3 ke4
gutt	骨头	gu3 tou2
livet	礼物	li3 wu4
lime	礼貌	li3 mao4
bakken	把控	ba3 kong4

Translations

Norwegian words	Chinese characters	Pinyin
massasje	按摩	an4 mo2
bandasje	创口贴	chuang4 kou3 tie1
øl	啤酒	pi2 jiu3
språk	语言	yu3 yan2
sitron	柠檬	ning2 meng2
laks	三文鱼	san1 wen2 yu2
jordbær	草莓	cao3 mei2
bibliotek	图书馆	tu2 shu1 guan3
dyr	动物	dong4 wu4
senter	中心	zhong1 xin1

Unrelated

Norwegian words	Chinese characters	Pinyin
luft	黄瓜	huang2 gua1
verden	房子	fang2 zi
landet	牛肉	niu2 rou4
måte	客车	ke4 che1
jorden	空间站	kong1 jian1 zhan4

navn	森林	sen1 lin2
bilde	辣椒	la4 jiao1
fisk	名家	ming2 jia1
farge	强敌	qiang2 di2
jente	芹菜	qin2 cai4

English to Chinese:

Cognates

English words	Chinese characters	Pinyin
bagel	贝果	bei4 guo3
muffin	麦芬	mai4 fen1
punk	朋克	peng2 ke4
cartoon	卡通	ka3 tong1
cheese	芝士	zhi1 shi4
chiffon	雪纺	xue3 fang3
guitar	吉他	ji2 ta1
hamburger	汉堡	han4 bao3
jacket	夹克	jia2 ke4
lace	蕾丝	lei2 si1

Sound-alikes

English words	Chinese characters	Pinyin
church	车子	che1 zi
colour	可乐	ke3 le4
ending	安定	an1 ding4

camel	楷模	kai3 mo2
chef	闪付	shan3 fu4
coach	口吃	kou3 chi1
plan	破烂	po4 lan4
region	热诚	re4 cheng2
move	木屋	mu4 wu1
judge	榨汁	zha4 zhi1

Translations

English words	Chinese characters	Pinyin
ability	能力	neng2 li4
audience	观众	guan1 zhong4
benefit	效益	xiao4 yi4
brother	兄弟	xiong1 di4
change	变化	bian4 hua4
city	城市	cheng2 shi4
data	数据	shu4 ju4
energy	能量	neng2 liang4
factor	因素	yin1 su4
garden	花园	hua1 yuan2

Unrelated

English words	Chinese characters	Pinyin
investment	哀愁	ai1 chou2
husband	爱护	ai4 hu4
season	案情	an4 qing2

threat	芭蕉	ba1 jiao1
worker	霸道	ba4 dao4
wind	白色	bai2 se4
voice	电报	dian4 bao4
trade	独白	du2 bai2
street	丛书	cong2 shu1
record	风霜	feng1 shuang1

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