Morphological Processing in Bilingual Speakers of German and English

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Declaration

I declare that this work was carried out in accordance with the Regulations of the University of London. I declare that this submission is my own work, and to the best of my knowledge does not represent the work of others, published or unpublished, except where duly acknowledged in the text. No part of this thesis has been submitted for a higher degree at another university or institution.

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Abstract

It has been demonstrated that in early visual word processing, monolingual speakers process morphologically complex words in terms of their constituent morphemes (e.g., hunt+er), irrespective of the semantic relationship between stem and suffix (e.g., corn+er) (e.g., Longtin, Segui, & Halle, 2003; Rastle, Davis, & New, 2004). However, research into bilingual morphological processing has produced support for and against the notion that bilinguals process morphologically complex words akin to monolingual speakers (Clahsen, Felser, Neubauer, Sato, & Silva, 2010; Diependaele, Duñabeitia, Morris, & Keuleers, 2011).

The experiments in this work explored the nature of bilingual morphological processing in early visual word recognition, by means of masked priming. Using prime target pairs sharing a morphological and semantic (e.g., hunter-hunt), only a pseudo-morphological (e.g., corner-corn), and neither morphological nor semantic relationship (e.g., yellow-yell), Experiments 1 and 2 explored morphological priming in English for English L1 – German L2 and German L1 – English L2 speakers, respectively. The design was expanded to German, testing bilingual German L1 and L2 speakers in Experiments 3 and 4. Results showed similar trends with consistent priming across all conditions for bilingual English L1 and L2 speakers, but different priming magnitudes for bilingual German L1 and L2 speakers. Using primes ranging from very low to very high frequencies, the relative contribution of prime frequency with respect to these findings was explored first for native English speakers in Experiment 5, and expanded to English L2 speakers in Experiment 6. Although prime frequency affected reaction latencies in both monolingual and bilingual speakers, Experiment 7, a re-test of Experiment 1 with monolingual speakers with no knowledge of a foreign language, indicated that it may be the sound command of another language that influences morphological processing in the participants' native language. The results are discussed in relation to the current literature and models of bilingual word processing.

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Table of Contents

List of Tables

List of Figures

Chapter 1

Word Formation and Morphology in English

1.1 Introduction

Morphology Gains Recognition in Research

Before the 1960s, morphology was not considered as a subject of study in its own right, neither within linguistics nor psychology, although the study of words and their classifications was a dominant feature of ancient grammars such as Latin and Greek (Matthews, 1991). Morphology was regarded as a part of the language system that could be fully explained and accounted for by both syntax and phonology, and thus any notion of morphology as being worthy of independent study was non-existent (Aronoff, 1976). Although Chomsky was not originally in favour of a word-based approach to morphology, his distinction between deep syntax and surface syntax (Chomsky, 1965) brought about some change in attitudes towards morphology. Within this framework, surface syntax treats morphologically complex words, such as *trying*, as complete units, whereas deep syntax breaks down morphologically complex structures into different components (Matthews, 1991). Although Chomsky suggested that morphology should be treated as separate from syntax, he did not propose a theory of morphology himself (Aronoff, 1976). Several authors, however, have published works on the internal structures of words, demonstrating how morphology is the basis for word formation (e.g., Aronoff, 1976; Bauer, 1983; Marchand, 1969; Matthews, 1991). A selection of these works will form the basis of this chapter on morphology in English.

1.2 The Morpheme

As described above, morphology is the study of the internal structure of words. Thus, morphology focuses on the basic units of words, called morphemes. Morphemes can therefore be regarded as the minimal units of grammatical analysis (Bauer, 1983; Matthews, 1991). However, this does not mean that each individual morphological unit must bear a semantic meaning independent of the larger unit it can be attached to, or that its meaning can be ascertained independent from a syntactical context. In fact, it has been argued that the premise to define a morpheme as the minimally meaningful bearing unit is *'misguided'* (Aronoff, 1976, p. 7). For example, the word *unmentionables* can be segmented into the morphemes *un·mention·able·s*. The inflectional suffix *–s* in isolation may denote either a plural noun, or an inflected verb form in the third person singular. In the present example, it denotes the former. However, this can only be specified once the morpheme has been attached to the word itself. Thus, morphemes should be regarded as basic, or 'primitive' (p.12) units that can be arranged in a grammatical order to form words, phrases and sentences (Matthews, 1991).

Before some of the main aspects of the study of morphology, such as inflection and derivation, can be discussed, definitions of some basic terms, as well as the characteristics of monomorphemic words taking on affixes to form morphologically complex words, are required.

1.3 Lexeme

A lexeme is an abstract term referring to all word forms a particular word can take. For example, the word *perform* can appear in several variants such as *perform*, *performs, performed, performing*. Thus, all these examples are, in this case, variants, or lemmas, of the lexeme *perform* (Carstairs-McCarthy, 2002).

1.3.1 Root/Stem/Base

The terms root, stem and base are often used to refer to the component of a word that remains when all affixes have been stripped. However, although these terms are often used interchangeably, some (e.g., Bauer, 1983) argue that they possess distinct meanings. A **root** is regarded as the part of the word that is retained when all elements of both inflectional and derivational morphology have been removed and the remainder cannot be broken down further into any other morphemes. For example, the word *untouchables* (Bauer, 1983, p. 20) can be broken down into the morphemes *un·touch·able·s*. Once the morphemes *un-, -able, and -s* have been removed, only the root *touch* remains which cannot be broken down into any additional morphemes. Thus, once a root has been identified, it can only be analysed further in terms of etymology (Matthews, 1991). Roots are not always free morphemes that can stand alone, but may also function as bound morphemes. Carstairs-McCarthy (2002, p. 20) provides the following examples a, and b, (roots denoted in bold):

a, Free roots:	**read**·able	b, Bound roots:	**leg**·ible
	hear·ing		**audi**·ence
	white·ness		**clar**·ity

Bound roots are often more difficult to identify compared to free roots, and there are some bound roots that only occur once within the English language. Such bound roots are termed Cranberry morphs and relate to words such as *cran·berry* and *huckle·berry,* whereby neither *cran-* nor *huckle-* appear in any other English word or independent of the above examples (Aronoff, 1976, p. 10). As such it is not possible to attribute meaning to *cran-* and *huckle-* (or *audi-* and *clar-* in example b) independent from the morphemes these roots are bound to. However, Carstairs-McCarthy (2002) also demonstrates that although bound roots such as *audi-* do not have an inherent meaning of their own, they can appear in several other words, such as *audi·tory,* and *audi·tion* (p. 21). In the English language a word may also consist of two free standing root morphemes through compounding, such as in the words *motor·bike* or *pen·knife*. Just as a compound can contain two free root morphemes, it can also consist of two bound roots, such as *micro·cosm* or *electro·lysis* (Carstairs-McCarthy, 2002, p. 21). In these examples, neither of the bound roots can stand alone (although *micro-*, *macro-*, and *retro-* are sometimes encountered as free standing morphemes) to provide fully comprehensible meaning; compounds consisting of two bound roots are a rare occurrence in the English language.

Bauer (1983) defines a **stem** as the component of the word that remains when all inflectional morphemes of a word have been removed. Thus, a stem only takes on inflectional suffixes. For example, the word *connections* consists of the root *connect.* The stem, however, contains all morphemes except for the inflectional pluralisation *–s*. Thus, the stem in this example is *connection.* A stem can also consist of two free roots, such as in the word *pen·knife·s*; here the stem is *penknife* (Carstairs-McCarthy, 2002).

To the **base** form of a word the process of affixation (see below) can be applied. Thus, a base can take on any prefix or suffix, and as such, and contrary to stems, a base only takes derivational affixes (Bauer, 1983). For example, the base of the word *unmanageable* is *manage* which can take the derivational affixes *un-* and *–able.* In turn, the base *manageable* may also take the affix *un-*. Thus, unlike roots and stems, a base that has already taken an affix can still function as a base taking an additional affix (Bauer, 1983). For example, the word *helpful* consists of the root/base *help,* which by taking on the suffix *–ful* forms the base *helpful*, which, by taking on the suffix *–ness,* forms the morphologically complex word *helpfulness* (Carstairs-McCarthy, 2002).

1.4 Affixation

The morphological process whereby words are generated through the addition of morphemes to a base, is called affixation (for a comprehensive list of English affixes and their frequency of occurrence, see Appendix 1). Morphemes such as *de-, en-, re-,* and *un-*, may be added before a base, resulting in the process of *prefixation*. For instance, the base *introduce* can take on the prefix *re-* by which the word *reintroduce* is formed. As outlined in Bauer (1983), most prefixes do not change the syntactic class of the base they are attached to (the following examples can be found in Bauer, 1983, p. 217-220). This applies, for instance, to the prefixes *mini-* (e.g., *minidress*), *step-* (*stepmother*), and *mal-* (*malnutrition*). There are, however, some exceptions and a few prefixes, including *de-(debunk)*, *dis-(disbar)*, *non-(non-stick)*, and *un-(unman)*, that may result in a class change of the base. The prefix *a-*, for example, can change a noun or a verb, or a word with an ambiguous class categorisation, into an adjective. Attaching *a-* to the word *sleep,* which can be both noun and verb, forms the adjective *asleep*. Similarly, *a- + blaze* forms the adjective *ablaze*. Other examples of this relate to the prefixes *be-* (e.g., *bewitch*) and *en-* (e.g., *ensnare*) which can transform nouns, and sometimes verbs and adjectives, into transitive verbs that require both direct subject and object relations.

Similarly as demonstrated for prefixation, a morpheme can also be added at the end of the base (e.g., *-age*, *-ing*, and *-er*), resulting in a process called *suffixation*. This is a far more common occurrence than prefixation, as the English language contains many more suffixes than prefixes. For instance, the base *walk* may take on the suffix -er, which is a nominalisation suffix and turns a verb into a noun, thereby forming the word *walker*. As demonstrated above, only root morphemes can be free standing (exceptions as outlined above), and thus the affixes added to the base must be bound and cannot stand alone (Carstairs-McCarthy, 2002).

The following suffixation examples are based on a more detailed discussion in Bauer (1983, p. 220-226). Suffixes attached to verbs can result in the nominalisation of the base form. For instance, when attached to verbs, the suffix *-ation* result in nominalisation, e.g., *flirt·ation.* Other nominalisation suffixes include *-ure (closure), -al (dispersal), -er (walker),* and *-ment (management)*. Suffixation can also form nouns from adjectives, e.g., *-cy (excellency), -ce (dependence), -ist (socialist),* or *-th (warmth)*. Some suffixes derive verbs from nouns or adjectives, such as the suffix -ise (e.g., *marginalise*), or *-en* (e.g., *toughen*). However, although there are suffixes that result in noun to noun derivatives, the English language does not appear to allow for verb to verb suffixation. Other examples for word formation processes through suffixation include the formation of adjectives from nouns (e.g., *-al, environment·al*; *-ate, passion·ate; -ous, poison·ous);* and adjectives from verbs (e.g., *-able, trace·able; -ive, generative)*. Some suffixes also form adverbs from nouns (e.g., *-wards, heavenwards*). Although suffixation often results in class changes of the base, it may also retain the class of the base. For example, for nouns, the suffixes *-dom (kingdom), -ette (kitchenette)* or *-ling (earthling)* all preserve the class of their bases. Similarly, the suffix *-ish* can preserve the base class when attached to adjectives *(warm·ish).*

1.5 Inflection

In order to define the meaning of inflection, it is helpful to understand how it differs from derivation. According to Stump (1998), derivational processes lead to the formation of two expressions that differ in their lexical meaning (e.g., *agree* -

agreement), whereas in inflection, formed expressions will share both their lexical meaning, as well as their part of speech, in other words, the lexical category a word belongs to (e.g., noun, verb, adverb, participle, pronoun etc.) Thus, inflections, contrary to derivations, should not result in category change. However, as demonstrated above (suffixation), this is not a sufficient criterion to distinguish inflection from derivation, as there are instances in derivation whereby the category of a word is maintained during suffixation. In addition, derivation does not always change lexical meaning as demonstrated by Stump (1998) with *cyclic* versus *cyclical* (p. 15). Thus, additional criteria to define inflection are needed. Stump (1998) makes the following suggestions. Inflection may be required by the syntactic context within which a word is placed. For instance, certain auxiliary verbs demand the past participle form of a verb, which is easily demonstrable for irregular verb forms such as *beat*. For instance, the auxiliary verb *have* demands the verb to take on the past participle form in order to form a present perfect (e.g., he *has been beaten* before) (see Ungerer, 1995). Inflections also tend to be more semantically regular than derivations (Stump, 1998). In other words, inflected verbs tend to retain their meaning (compare *sing* with he *sings*), whereas derivations in general alter the semantic content of the word that has been formed through suffixation (compare *hospital* (i.e., a place where sick people receive medical treatment) with *hospital·ise* (i.e., the process by which people are placed in a hospital) (Stump, 1998, p. 17). In addition, derivations but not inflections tend to be listed in the dictionary, as the semantic relationship between a derivation and its base may change over time as language develops (e.g., *winter* – *winterise*) (p. 17). Inflections, however, are not normally listed as separate dictionary entries, as it is assumed that they retain a close semantic relationship with their base. One additional criterion to define inflection as separate from derivation described by Stump (1998) is that of closure. It can be assumed that in the English language, once a word has been inflected, further inflection or derivation thereof is not possible (e.g., an inflected verb *sings* (3. person singular) cannot be converted into a derivative, e.g., *sing·s·er*). However, further derivation of an already suffixed word is possible (e.g., *hope·ful·ness*).

In summary, no single criterion is sufficient to describe how inflection differs from derivation. As the above analysis shows, inflection can be defined by several criteria. The following section will demonstrate some of the forms of inflectional change in words.

1.5.1 Specification Changes

One way in which inflection changes the specifications of single words is in terms of person and number. For example, the verb *sing* can be inflected in the following way:

(1) sing (1st Person, singular, e.g., I sing)
(2) sing (2nd Person, singular, e.g., you sing)
(3) sings (3rd Person, singular, e.g., he/she sings)
(4) sing (1st Person, plural, e.g., we sing)
(5) sing (2nd Person, plural, e.g., you sing)
(6) sing (3rd Person, plural, e.g., they sing)

It becomes apparent very quickly that in all the above examples, with perhaps the exception of (3), both person and number will have to be deducted from the syntactic context in which the verb *sing* occurs. If presented in isolation, it is impossible to specify whether *sing* refers to a single person, or many. It can nevertheless be argued that examples 1, 2, 4, 5 and 6 are all inflectional variants of the lexeme SING (Carstairs-McCarthy, 2002), although their exact specifications will be context dependent.

1.5.2 Noun Inflection

Most plural nouns in English are formed by adding the suffix *–s* to a singular noun, e.g., *house – houses.* As demonstrated by Muir (1974), this may lead to changes in spelling as well as pronunciation. For example, nouns ending in *–y* drop their last letter when the plural is formed and take on *–ie*, e.g., *baby – babies*. Some words undergo a process of irregular inflection when the plural of a noun is formed, leading to a vowel change instead of taking on the *–s* suffix, resulting in changes in both spelling and pronunciation, e.g., *man-men*, *louse-lice*, *tooth-teet*h. Also, for nouns ending in *–f*, when the plural is formed, the last letter is dropped, and the consonant *–v* as well as the ending *–es* is taken on instead, e.g., *calf-calves*, *wolf-wolves*. This pattern also applies to nouns ending in *–fe*, e.g., *knife-knives*, *wife-wives*. Within the English language, there is only one noun for which the plural is formed by attaching the suffix *–en*, which is *oxen* (Bauer, 1983, p. 8). A special case of pluralisation relates to so-called zero suffix nouns, and most occurrences of those zero plural nouns can be found for animals, e.g., *fish, sheep* or *deer* (Carstairs-

McCarthy, 2002). In syntactic contexts, singular and plural forms can be distinguished by accompanying indefinite or definite articles, or number words, such as *a fish* (singular), *the sheep* (plural) or *two deer* (plural), respectively (Carstairs-McCarthy, 2002).

1.5.3 Adjective Inflection

An additional feature of inflection is the formation of a comparative. This function applies to adjectives only. Many, but not all adjectives (see below for a detailed explanation) can take on the suffixes *–er*, and *–est* to form a comparative and a superlative, respectively (Carstairs-McCarthy, 2002; Greenbaum, 1991).

The following examples illustrate this principle:

absolute	**comparative**	**superlative**
nice	nicer	nicest
great	greater	greatest

It has been argued that comparatives should fall into the category of inflectional rather than derivational morphology, as the syntactic context of the sentence often demands the comparative, and other solutions would result in a-grammatical sentence constructions (Carstairs-McCarthy, 2002). For example, in order to compare two emotional states, ‘today, I feel *happier* than yesterday’ cannot be changed into ‘today, I feel *happy* than yesterday’. Some adjectives, e.g. *good* and *bad*, take on irregular inflections (*good, better, best*; *bad, worse, worst*). In general, all one-syllable adjectives can take on *–er* and *–est*, whereby adjectives ending in *‘e’* will drop this vowel (e.g., *nice – nicer*); two-syllabic adjectives ending in *-le, -er, -y,* and *-ow* may also take on *-er* and *-est*, whereby the consonant *-y* will be exchanged by the vowel *–i (*e.g., *happy-happier*) (Ungerer, 1995). For all remaining two-syllable, and three-syllable adjectives, the comparative is formed using *more* and *most,* e.g., *more famous*, *most famous* (Ungerer, 1995).

1.5.4 Regular versus Irregular Verb Inflection

As already demonstrated (see 1.5.1 Specification Changes), inflection of the English verb may lead to changes in both person and number. Verb inflection, however, can also change the word tense and thus indicate whether an action was performed in the past or is still on-going. The simple past and past participle of the majority of verbs in English are formed using regular inflection, whereby the past tense suffix –*ed* is attached at the verb stem (e.g., *walk-walked*); the simple past and past participle of regularly inflected verbs are identical. However, there are more than 150 verbs in the English language for which the simple past and past participle cannot be formed by attaching to suffix *–ed*. These verbs are commonly referred to as irregular verbs. Greenbaum (1991) argues that there are seven different types of irregular verb inflections, which are outlined below:

1) The vowels of the verbs in category 1 are identical across all three forms (stem, past tense, past participle), examples include *bend - bent - bent; make - made - made; spoil - spoilt - spoilt;* some of the verbs in this category can also be inflected regularly (e.g., *earn - earned - earned*).

2) In this category, verbs like *saw - sawed - sawn* form a regular past tense with the suffix *–ed*, but add an *–n* inflection in the past participle; for some verbs, the past participle also includes a vowel change (e.g., *swell - swelled - swollen*).
3) Verbs in this category show the same vowel change for both past and past participle form (e.g., *buy - bought - bought; say - said - said*), and some past and participle forms also have regular inflectional endings (e.g., *dream – dreamt - dreamt* versus *dream -dreamed - dreamed*).
4) In category 4, all verbs in the participle form end in *–n* (e.g., *see - saw - seen*). However, for some verbs, a vowel change occurs in the past form (e.g., *blow - blew - blown*); for some vowels the past and participle form are identical (e.g., *tear - tore - torn*), and for some, all three forms are characterised by vowel changes (e.g., *write - wrote - written*).
5) In this category, all three forms of the verb remain identical, and thus the correct tense can only be identified from the syntactic context (e.g., *fit - fit - fit; cut - cut - cut*).
6) For verbs in category 6, the past and participle forms are identical but distinct in pronunciation from the stem (e.g., *bleed - bled - bled; get - got - got*).
7) Verbs in the last category can have no vowel similarities for any of the three forms (e.g., *begin - began - begun*), or have identical stem and participle forms (e.g., *come- came - come; run – ran - run*).

Some irregular verbs, however, are not commonly regarded as inflectional forms of one and the same lexeme. For example, the past tense and participle forms of the verb *go* (*go - went - gone*) can be argued to be phonologically distinct from the many other variants of the lexeme GO (*go, going, goes*), and therefore should not be regarded as allomorphs of the root morpheme *go*, but rather as separate, but related root morphemes thereof (Carstairs-McCarthy, 2002). This special case of irregular inflectional morphology is called ‘suppletion’ (p. 33), and it can therefore be said that both *went* and *gone* stand in suppletive relationship to the root morpheme *go* (Carstairs-McCarthy, 2002).

1.5.5 Verbs and *–ing*

The suffix *–ing* is often attached to verbs to form a progressive participle, denoting an action that will take place in the near future (e.g., she is *flying* to Rome tomorrow). In addition, actions taking place in the moment of speaking also demand verbs to take on *-ing*, thereby forming the present progressive tense, e.g., *I am just watching a film* (Ungerer, 1995).

1.6 Derivation

Having discussed inflection above, the remaining primary morphological process by which words are formed through affixation is called derivation. Beard (1998) explains that in comparison with inflection, a derivational process is purely lexical, not syntactical, and can thus change the lexical category of a word (whereas inflectional processes tend to maintain the lexical category of a word). Also, in derivation, and here again this contrasts with inflection, the process of affixation is not necessarily productive (see also below for productivity). A derivational word form is most commonly constructed by attaching a suffix to a base (e.g., *observe* (base); *observ·atory, observ·ation, observ·er;* here, the vowel 'e' is dropped when the base takes on a derivational suffix), thereby forming a new word, although some derivatives can also be formed by attaching a prefix before a base (e.g., *legal* (base), *il·legal*; *relevant* (base), *ir·relevant*). However, before this process will be explained in more detail, one derivational exception has to be noted. Some words, such as *hope* or *fear*, cannot easily be classified as belonging to either a verb or noun category. Carstairs-McCarthy (2002) demonstrates that under certain syntactic conditions, a derivational process can take place without the addition of a suffix. For example, in the sentences '*She hopes for better weather',* the word *hopes* can clearly be identified as verb of third person singular in the present tense. However, considering the phrase *'Her hope for better weather...',* it can no longer be argued that *'hope'* is a verb, but a verb derivative. This derivation without suffixation is sometimes referred to as 'zero-derived' (p. 48), thus the word becomes an un-suffixed noun (Carstairs-McCarthy, 2002). Another conventional term used for words that have changed class through zero-derivation is conversion. Thus, a conversion is a process by which a word, such as *hope*, belonging to one class (i.e., verb) is converted to another class (i.e., noun) without taking on a suffix, thereby retaining their original form (Carstairs-McCarthy, 2002).

1.6.1 Types of Derivatives

Derivatives can be formed from a variety of word classes. The most common examples are listed below.

1.6.2 Adverb Derivatives

The suffix *–ly,* when attached to a great number of adjectives, results in an adverbial derivate thereof, e.g., *soft – softly* (Carstairs-McCarthy, 2002). The suffix –*ly* however, is also an adjectival suffix, and can, for example, be attached to nouns to denote re-occurring events, e.g., *weekly, monthly* (Marchand, 1969, p. 330). Some adverbs are also formed by conversion, such as *fast*, and therefore do not require an additional suffix. A further adverbial suffix is *–al*. Derived from Latin, this suffix attaches to many Latinised English bases, such as *accidental*, *electoral*, or *hormonal* (Marchand, 1969, p. 238).

1.6.3 Adjective Derivatives

Adjectives can be formed through suffixation of other word classes. For example, the suffix *–ish* can be attached to a variety of nouns to form adjective derivatives such as *hellish*, *stylish*, or *bookish*. It can also be attached to numerals to denote an approximate age, e.g., *a fortyish woman* (Marchand, 1969, p. 306). Some of the most common suffixes added to nouns and verbs to form adjective derivatives are presented in the following list (based on Greenbaum, 1991):

-able / -ible	(e.g., profitable, fashionable)
-al / -ial	(e.g., postal, editorial)
-ed	(e.g., crooked)
-ful	(e.g., mindful)
-ic / -ical	(e.g., poetic, paradoxical)
-ish	(e.g., flourish)
-ive / -ative	(e.g., selfish, affirmative)
-less	(e.g., careless)
-ous / -eous / -ious	(e.g., disastrous, spontaneous, spacious)
-y	(e.g., wealthy)

1.6.4 Noun Derivatives

Noun derivatives may be formed from a range of suffixes attached to verbs and adjectives. The most common noun-forming suffixes (Carstairs-McCarthy, 2002; Greenbaum, 1991) include

-al	(e.g., committal)
-ance / -ence	(e.g., performance, preference)
-er / -or	(e.g., builder, actor)
-ing	(e.g., briefing)
-ism	(e.g., radicalism)
-ity	(e.g., reality)
-ion / -(a)tion	(e.g., infection, organisation)
-ness	(e.g., goodness)

1.6.5 Verb Derivatives

As demonstrated for adverbs, adjectives and nouns above, verbs can also be formed by attaching affixes to nouns. Although in English derivational morphology the majority of derivations are formed with suffixes, some verb derivatives are formed by attaching prefixes before a base (Carstairs-McCarthy, 2002). For example, *en-* or *em-* can form verbs from nominal bases, such as *enslave* or *empower*. Another example of verb derivation relates to adjective bases and the suffix *–en.* For a verb to be formed by attaching the widely used suffix *–en* to an adjective base, the adjective has to end either in a fricative (i.e., sounds spelled s, th, f, and v) or a plosive (i.e., sounds spelled b, p, d, t, (c)k, and g), thereby forming verbs such as *deepen*, *tighten*, or *loosen* (Carstairs-McCarthy, 2002, p. 56; Marchand, 1969). Other examples of suffixes forming verbs include (see Greenbaum, 1991)

-ate / -iate	(e.g., validate, differentiate)
-ify / -fy	(e.g., notify, simplify)
-ise / -ize	(e.g., characterise, criticize)

1.6.6 Class Maintaining Derivational Processes

The characteristic of a derivation is not in the first place a class change but a change in meaning. Thus, suffixation does not necessarily result in a change of class; therefore a noun may remain a noun albeit undergoing some form of semantic change. For example, the suffixes *–let, -ette*, and *-ling* can result in a diminutive form of a noun, e.g., *streamlet, kitchenette, duckling*, respectively (Marchand, 1969,

p. 326). Conversely, the suffixes *–ess*, or *–ine* are often used to form female parallels to male nouns, denoting a title or position, e.g., *princess*, or *heroine* (Marchand, 1969, p. 286). In similar fashion, the suffixes *–i* (see Bauer, 1983), or *–er* indicate a form of residency or nationality, e.g., *he is an Israeli / Londoner*. Class preservation also applies to some verbs (often through prefixation, e.g., *arrange – rearrange*), as well as adjectives (e.g., *-ish, brownish; un-, unhappy*) (Carstairs-McCarthy, 2002).

1.7 Productivity of Affixes

One important aspect that is intrinsically linked to derivational morphology is that of morphological productivity, responsible for the breadth of a language's vocabulary as well as the many neologisms added regularly to the language (Algeo, 1993; Bauer, 1983). There are several ways to assess the productivity of affixes. The most straightforward would seem to be a count of the number of times a given affix is attached to a base. However, Aronoff (1976) proposes several objections as to why this method cannot account well for the actual productivity of the affixes in question. First of all, simply counting the number of recorded occurrences of a derivational affix in a word corpus does not take into account the types of morphological bases these affixes are attached to, thereby ignoring necessary prerequisites of form of the bases (Aronoff, 1976). Secondly, this method depends on the assumption that every time a new word is formed with a particular affix, this representation is also entered into a list or dictionary. However, it is not possible to calculate a precise ratio between the possible and actual occurrences of an affix in a given language. Thus, the method of counting the number of times a certain affix appears in a lexical corpus does not provide a good account of its productivity (Aronoff, 1976).

In practice, there are two main methods used to assess the productivity of affixes. These are productivity of form and shape, and semantic productivity, whereby productivity of form and shape relates to the characteristics of the base as well as the affix itself, and semantic productivity relates to regularity in meaning (Carstairs-McCarthy, 2002).

1.7.1 Productivity Related to Form and Shape

One way to demonstrate what is meant by productivity of form and shape is to compare the use of several suffixes. Aronoff (1976) for example discusses *–ness* and *–ity* (p. 37-45), both forming abstract nouns from adjectives (see also further discussions on these two suffixes in Bauer, 1983; Carstairs-McCarthy, 2002; and Matthews, 1991). Both suffixes can be attached to a wide range of adjectives; however, they cannot be attached to adjectives ending in *–ous* (e.g., *fabulous*) to the same extent. The suffix *-ness* is said to be formally regular, enabling a prediction of the necessary characteristic of the base taking on this particular suffix (Carstairs-McCarthy, 2002). Thus, *-ness* can be attached to the majority of adjectives and form a plausible noun, which may however not be in conventional use (e.g., *longness* versus *length*, p. 86). In contrast, suffixes such as *–ity* and *–th* are less formally regular, because attaching either to a range of adjectives can result in nouns that have no apparent interpretable meaning, e.g., *greyth*, or *richity* (Carstairs-

McCarthy, 2002, p. 86). The suffix *–ity*, for example, can only attach to adjectives having certain endings, (e.g., *-ive (passive)*, *-able (capable)*, *-ar (insular)*, etc.) (Carstairs-McCarthy, 2002). In fact, all words it can attach to must be Latinate in origin, as opposed to native English (with the exception of *oddity*) (Aronoff, 1976). This contrasts for example with the suffix *–hood*, which can only attach to native bases (with the exception of those being etymologically Latinate, e.g., *priesthood*), as well as with the suffix *–ness*, which can attach to both Latinate and native bases (Aronoff, 1976). However, the characteristics of the base are not the only restrictions for formal regularly. As Carstairs-McCarthy (2002) points out, there may be phonological aspects that influence the type of base a suffix can attach to. For example, only when a base's final syllable ends in stress, the suffix *–al* can be attached (e.g., *proposal, committal),* with the exception of the word *burial*. Similarly, as also pointed out above (see 1.6.5 Verb Derivatives), the suffix *–en* can only be attached to monosyllabic verbs ending in plosives or fricatives.

1.7.2 Productivity Related to Meaning

The second component of productivity relates to semantic regularly. Semantic coherence differs between suffixes, and Aronoff (1976) again demonstrates this with the examples of *–ness* and *–ity*, arguing for a direct link between semantic coherence and productivity of morphemes. He shows that all nouns ending in *–ousness* (e.g., *callousness*) can only take on three possible meanings (p. 38), which are 'the fact that Y is Xous (e.g., *her callousness*), 'the extent to which Y is Xous' (e.g., *his callousness was hurtful*), and 'the quality or state of being Xous' (e.g., *callousness is a bad trait*). Because nouns ending in *–ousness* cannot take on any other meanings, they are said to be semantically coherent, and thus demonstrate the semantic productivity of the suffix *-ness*[1](Aronoff, 1976). In comparison, *-ity's* characteristics are less semantically regular, in that it can, but need not, take on all the possible meanings achieved by *–ness*. In addition, adjectives ending in *–ity* can also take on many more meanings, thus it is very difficult to predict the meaning of an adjective taking on *–ity*. For example, as outlined in Carstairs-McCarthy (2002), -*ity* can indeed change an adjective's meaning in an unpredictable fashion. *Selectivity*, for instance, is not synonymous to selectiveness as one would predict, but tends to refers to the quality of radio reception; *locality* (e.g., a health care locality team) relates to the meaning of neighbourhood, and not as predicted, a specific location, just as the noun *partiality* does not commonly indicate incompleteness, but favouritism (see Carstairs-McCarthy, 2002, p. 88-89). Thus, productivity is intrinsically linked to predictability of meaning and semantic coherence.

1.7.3 Productivity and Semantic Blocking

There are some instances in the English language whereby a highly predictable word formation is impossible due to the existence of an alternative word with the same meaning. This phenomenon is called (semantic) blocking (Aronoff, 1976, p. 43), and can be illustrated with the following example: the suffixes *–let* and *–ling* denote diminutive forms of nouns (Marchand, 1969), such as *piglet* or *gosling*.

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[1] Although *–ness* is regarded as semantically productive, Carstairs-McCarthy (2010) demonstrates that this suffix can also lead to word formations that are semantically arbitrary. For example, he points out that *highness* is not synonymous to *height* as predicted, but generally denotes a person of aristocratic background. Similarly, *goodness* in some instance does not refer to positive character traits, but to nutritional value, e.g., *there is a lot of goodness in those greens*.

However, forms such as catling or cowlet do not exist, as alternative forms of *kitten* and *calf,* respectively*,* are already established (Carstairs-McCarthy, 2002). Thus, blocking inhibits the formation of words for which there already exists an alternative that has precisely the same meaning, regardless of whether such words can be predicted from semantic regularity (see Carstairs-McCarthy, 2002). Another example is the blocking of certain *–ous* adjectives to take on the suffix *–ity* if a *–ness* form already exits (e.g., *glorious* – *gloriousness* – but not *gloriosity*; Carstairs-McCarthy, 2002, p. 91); however, if the *–ity* form already exists, an alternative –*ness* form is never blocked (e.g., *curious – curiosity – curiousness*) (Aronoff, 1976).

In summary, it can be argued that productivity of morphemes is essential for word formation processes and relies on both regularity of form and regularity of meaning. However, even though some new word formations may be highly predictable, their existence can be blocked by the existence of alternative forms, though there are several exceptions as noted above. Thus, the productivity of a morpheme can to some extent be defined by its ability to form new plausible and interpretable words (Bauer, 1983).

1.8 Morphology – Worthy of Study in its own Right

This chapter has outlined the main components of English morphology, including inflection, derivation, and productivity, and demonstrated that morphology is the basis on which new words are formed within the English language. Through suffixation processes, the meaning of novel words can be easily accessed. For example, the novel word ‘googling’ is understood as the process of searching on the ‘google’ search-engine, just as ‘downloading’ is commonly referred to as the process of retrieving material from the internet. Thus, through the application of morphology, language is continuously evolving, contributing to an ever growing lexicon of the English language. It is therefore important to study morphology in order to increase our understanding of how morphologically complex words are processed, and how individual morphemes contribute to how humans are able to create and understand novel words.

Although not exhaustive, the overview in this chapter has demonstrated some of the complexities of morphology and shown that morphology cannot be solely accounted for by syntax or phonology, although both play a role in the interpretability and pronunciation of many morphologically complex words. In the next chapter, psycholinguistic models of word processing and proposals for the processing of morphologically complex words will be discussed.

Chapter 2

Models of Visual Word Processing

2.1 Introduction

Chapter 1 provided an overview of the key mechanisms of morphological word formation in English (i.e., inflection and derivation), and demonstrated that morphology should be regarded as a subject worthy of study in its own right. This chapter provides a brief overview of a selected number of models of visual word processing, with the aim to demonstrate how different models can potentially account for the processing of simple as well as complex words. In this chapter, models are presented that have been based to varying degrees on the founding principles of one of the first computational models, the interactive activation (IA) model (McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982). Subsequently, models were further developed within both localist (e.g., Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; Davis, 1999; Giraudo & Grainger, 2000, 2001) as well as distributed connectionist (e.g., Gonnerman, Seidenberg, & Andersen, 2007; Harm & Seidenberg, 2004; Plaut & Gonnerman, 2000) frameworks. Most of these models attempt to provide an account of how visual input (i.e., the printed word) is processed and interpreted both orthographically (form) as well as semantically (meaning). The purpose of this chapter is not to provide a historical account of how models of word recognition were developed and adapted over time, but to provide a brief description of models and frameworks that attempt to explain visual word processing, with the potential to incorporate accounts of morphological processing, the focus of this thesis.

2.2 Models of Word Processing

2.2.3 The Interactive Activation Model (IA)

2.2.3.1 Architecture of the Interactive Activation Model

The Interactive Activation model (IA) (McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982) proposes that the processing of visually presented words takes place in a system consisting of several processing levels. These processing levels incorporate a visual feature level, a letter level, and a word level (see Figure 1). Later modifications of the IA model also include a syntactic level, a word-sense level, a non-linguistic scenario level capturing actions described during sentence processing, as well as a phoneme and auditory feature level for speech processing (McClelland, 1986). At each one of these levels, representations of the visual input are formed. Higher levels aid the processing of these representations through top-down facilitation (McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982).

In the IA model, visual processes operate in parallel and simultaneously at several levels. Thus, the model can process several letters at the same time. Another feature of the model is that it is interactive, and therefore both inhibitory and facilitatory processes operate simultaneously and between levels, meaning that representations at one level can be influenced by representations at another level. This is called bi-directional processing, and allows for active competition between interpretations to take place (McClelland, 1986). However, certain constraints within the model regarding the extent of interactivity were added over time as the model underwent a number of modifications and additions. For example, between-level interactions were set in such a way that they are excitatory only and can therefore only operate between adjacent levels (McClelland, 1986). This is so that activated patterns in one level will in turn excite compatible patterns in an adjacent level, but not inhibit incompatible patterns. Inhibition should take place through competition from activated patterns on the same level (within-level), so that the pattern that receives most support from a range of activated patterns will emerge as the dominant match in relation to the input into the model (McClelland, 1986).

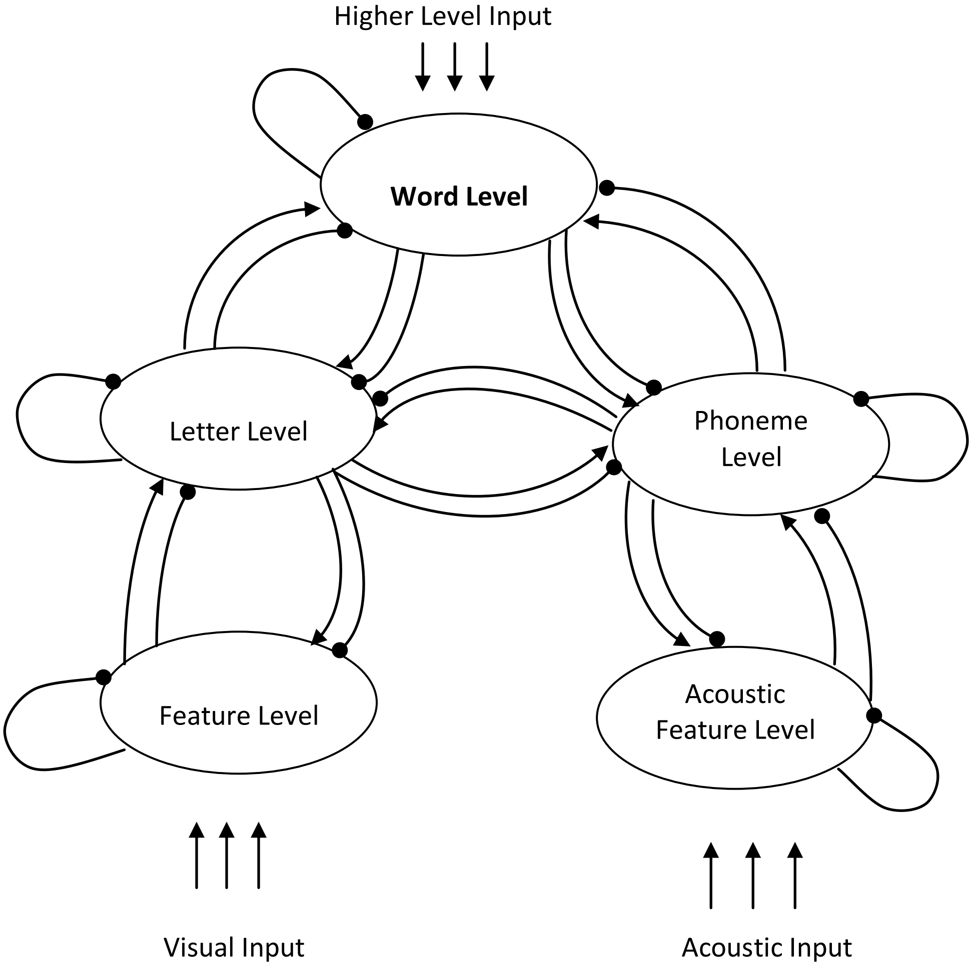

Figure 1. Processing levels involved in visual and auditory word processing. Redrawn from McClelland and Rumelhart (1981). Arrows denote excitations, and circles denote inhibition. Later modifications to the model no longer contain between-level inhibition.

The IA model specifies that relevant units in the system are represented by nodes (McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982). Thus, each word or each letter of a 4 letter-word that is fed into the model has a node representation. The model is organised in such a way that nodes are categorised into levels, with a word-level node, and a letter-level node. Crucially, nodes do not stand in isolation. Each node has a neighbour, although there are no connections between non-neighbouring levels. Thus, each node can be excited or inhibited, whereby excitation increases activation, and inhibition decreases activation. In terms of activation, each node within the system has a momentary activation value. Thus, if a node has positive action value, it is active, and conversely, if it has a negative action value it tends to receive inhibition. In the absence of excitation or inhibition, each node has its own resting level, which may differ between nodes. Specifically, high-frequency nodes tend to have higher resting levels compared to low-frequency nodes.

In this highly interconnected model, activated neighbours can also influence the activation levels of their respective neighbours through either excitation or inhibition. Letter features that have the most active feature nodes receive most activation. The model proposes that visually detected features send activation to all letter nodes that match those activated features (McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982). All others nodes not containing these features are inhibited. Therefore, when a stimulus is presented, some nodes' activation levels are excited above their resting level, whereas other nodes receive more inhibition and are thus inhibited below their resting level. Active competition between letter nodes results in only the strongest node being activated. Once word nodes become activated, they send feedback to the letter nodes. For example, the four letter word *work* will, once perceived, also activate other 4 letter words beginning with ‘w’ (e.g., *walk*, *wear*, etc.,) at the letter level (McClelland & Rumelhart, 1981). Because they only overlap in their initial letter position, their activation is weak and can be inhibited by other nodes. At the word level, *work* is then well activated and through feedback inhibits other nodes, until *work* itself exceeds a certain threshold level, leading to a drop in activation (McClelland & Rumelhart, 1981).

Crucially, the pattern of activation in the IA propagates gradually over time (McClelland, 1993), and the activation of word nodes rises gradually as a function of both top-down and bottom-up information. It is therefore assumed that when both context and word sources accumulate at the same time, this summed activation causes a certain activation threshold to be met faster. It is also important to note that the activation in the IA is not linearly, but monotonically related to the sum of the net activation (McClelland, 1986, 1993). This means that at each processing unit in the IA, a simple calculation is performed, by which the sum of all inhibition received from competing units is subtracted from the sum of all excitatory activation received, resulting in a sigmoid activation function, shaped by a single point of activation, and reduced activity at either ends of the function itself. The implementation of a monotonic rather than linear function in the IA prevents an extreme and explosive build-up of activation through bi-directional connections (McClelland, 1993).

2.2.3.2 Implementation of the IA

The computational implementation of the model included a corpus of 1,179 monomorphemic four letter words (McClelland & Rumelhart, 1981). Following initial simulations, parameters were set so that probability of feature extraction as well as the timing with which a masking stimulus was presented were free to vary. All other parameters were fixed. The model was able to simulate a range of data obtained from behavioural experiments (see McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982). For example, the model is able to account for experimental findings into bigram frequency effects (Broadbent & Gregory, 1968) that demonstrated advantages in whole word production for five letter low frequency words with low frequency bigrams. The model was able to replicate these findings for four-letter words (McClelland & Rumelhart, 1981), demonstrating that under conditions of degraded input, the model has difficulties recognising low frequency words that contain high frequency bigrams, as these kinds of words have many neighbours. If both high and low frequency words are equally detectable in terms of their visual features, the word nodes of the high frequency words are likely to receive more activation (McClelland & Rumelhart, 1981). Therefore, correct identification of a low frequency word depends in part on the presence or absence of high frequency neighbours that can also receive activation. However, neighbouring words also facilitate activation by means of strengthening feedback, thereby increasing the activation of the target word.

It was further demonstrated that the model is able to describe how pseudowords can activate word nodes of real words, if both the pseudoword and real word share letter representations (McClelland & Rumelhart, 1981). Pseudowords can activate actual words within the vocabulary by activating at least two nodes belonging to real neighbouring words. Through feedback this activation is strengthened, unless the letter-to-word inhibition is stronger compared to the letter-to-word excitation. For example, the pseudoword *mave* also activates words such as *more* or *many*, but their activation is quickly reduced (McClelland & Rumelhart, 1981). Words sharing up to three letters in common receive more activation. These activated nodes then interact with the actual target word, although pseudowords never result in quite the same level of activation of word nodes as real words do.

Further, the model demonstrates that letter identification is aided by the presence of contextual information (Rumelhart & McClelland, 1982). In other words, the duration of the presentation of different letter sequences was varied (e.g., presenting the letters S and HIP of the word ship in a 1:2 and 2:2 ratio, see Experiment 1, Rumelhart and McClelland, 1982). If contextual information is presented for longer, letter identification performance improves, especially if contextual information is presented prior to the target letter.

In summary, the model proposed by McClelland and Rumelhart (1981), and Rumelhart and McClelland (1982) provides an interactive-activation account of word processing, which takes into account bottom-up as well as top-down processing, and proposes that activation spreads in a graded fashion through inhibition and excitation. Simulations of the model show that the IA can account for the perception of visually presented familiar, as well as novel words. The IA model provided a stepping stone for a number of computational models to be put forward that expanded on or modified the original IA model. The following sections demonstrate how subsequent models were adapted to suit both localist as well as distributed connectionist frameworks.

2.3 Localist versus Distributed Connectionist Account of Word Processing

Following the seminal work by McClelland and Rumelhart (1981) and Rumelhart and McClelland (1982), two contrasting branches of modelling word recognition emerged. Some authors (e.g., Coltheart et al., 2001; Davis, 1999; Page, 2000) have been advocating a localist view of visual word processing, whereas other authors (e.g., Gonnerman et al., 2007; Harm & Seidenberg, 2004; Seidenberg & McClelland, 1989) have been promoting a distributed connectionist account of word processing. The principal notions of each account are briefly explained below.

Localist versus distributed account. In essence, the localist account proposes that every level within the model contains unique representations. Thus, it is argued that there are distinct representations or nodes for e.g., the word *grandmother* as well as for the concept of *grandfather* (Bowers, 2002, p. 414). It can thus be said that localist networks can be defined by the incorporation of completely distinct representations for discrete parts of information. It should therefore be possible to interpret any one node in isolation and as distinct from other nodes (Page, 2000). Distributed connectionist models on the other hand postulate that there is no direct mapping between one unit and a distinct representation (e.g., a word).

Rather, each unit is involved in activating several representations, and distinct units (e.g., words) are represented by the combined activation of several units (Plaut & Gonnerman, 2000). Therefore, words or pieces of information are encoded in a distributed fashion and as patterns of activations over multiple units (Bowers, 2002).

Before a brief overview of models within each framework is provided, it is important to note that some authors have suggested that an integrative approach of elements of both approaches would yield models that can account for a wide range of behaviours. For example, both Page (2000) and Bowers (2002) argue that connectionist models built with the capacity to learn localist representations support a number of phenomena, such as the word superiority effect. Bowers (2002) also points out that a pure distributed connectionist account to learning may not be desirable, and can lead to general activation patterns that prove counterproductive in relation to identifying the correct meaning of words (e.g., CHAIR is activated when CHAID in presented to the model, p. 422). An integration of the ability to learn localist representations can overcome such errors. In addition, an integrative approach would also overcome the difficulties many distributed models have in identifying novel morphologically complex words, such as CATPOLE (Bowers, 2002, p. 424) (see below for a comparison of localist and distributed accounts of morphological processing). It is important to note that Page (2000) points out that localist models do not and cannot deny the reality of some form of distributed representations. Crucially, he argues that although distributed elements are present in localist models, distinct meanings will be represented in a localist fashion on levels responsible for identifying the meaning of a given input.

2.3.1 Localist Models

The following section will provide a short overview of some of the most important models operating within the localist framework. This is followed by a selection of proposals from some researchers of how morphological processing might be implemented in localist models.

2.3.1.1 The Dual Route Cascaded (DRC) Model

The **Dual Route Cascaded (DRC) model** (Coltheart et al., 2001) (see Figure 2) is a computational model that builds on the work of Coltheart, Curtis, Atkins, and Haller (1993), as well as Coltheart and Rastle (1994), and Rastle and Coltheart (1998, 1999a, 1999b). The DRC is a model accounting for both reading aloud and visual word recognition. One important component of the model is that it is based on cascaded rather than threshold processing. This means that as soon as activation is received in one module of the model, it is passed on to subsequent modules. This contrasts with threshold processing that requires activation within a single module to build up and reach a certain predetermined threshold until activation is passed on to the next module. As outlined above for the IA model, processing in the DRC also operates in a graded but non-linear fashion (Coltheart et al., 2001). Unlike the IA, the DRC model is not restricted to four letter words. The orthographic lexicon of the model contains a corpus of 7,981 monosyllabic units (based on the CELEX database by Baayen, Piepenbrock, & van Rijn, 1995) ranging between one to eight letters in length. For each of these units, the phonological lexicon contains a corresponding unit, except for homophones (e.g., SO and SEW), totalling 7,131 units (Coltheart et al., 2001).

Once input is received by the visual feature units, it is passed on to the letter units before processing follows separate routes (see below). The visual feature level contains 16 feature units that can be set to on, and 16 feature units that can be set to off (coded as 1 and 0, respectively), depending on whether an input position contains a specific letter in a certain position. In the letter units, there are eight subsets for eight input positions (eight letters being the maximum length of any given word). Each subset in turn can code for all 26 letters of the alphabet in addition to one blank letter.

The DRC features two main routes (with a third non-implemented lexical semantic route, see below) each of which contains several layers encompassing several units (Coltheart et al., 2001). Akin to the IA, communication between the layers is achieved through excitation as well as inhibition. The model also allows for lateral inhibition between units (see also Figure 2). A few constraints on communication are also implemented in the DRC, in so far that only excitatory communication can take place between the orthographic and phonological lexicon units; also, activation from the visual feature units to the letter units is unidirectional (see also Figure 2). Once activation has reached the letter units, processing continues simultaneously via two separate routes, a lexical non-semantic route, and a grapheme-to-phoneme correspondence (GPC) route, until the two routes converge again for word pronunciation. In the lexical non-semantic route, a word's letter features activate the word's corresponding letter units. Activation then spreads in cascaded fashion from level to level, activating the representation of the word on each level until the phoneme unit receives activation and the word can be pronounced. In the GPC route on the other hand, grapheme-to-phoneme correspondence rules are applied to translate letters into phonemes. Words are processed in serial fashion, letter by letter, from left to right. In the actual implementation of the model, on each cycle, the GPC route attempts to find the correct phoneme rule to match the letters presented (Coltheart et al., 2001).

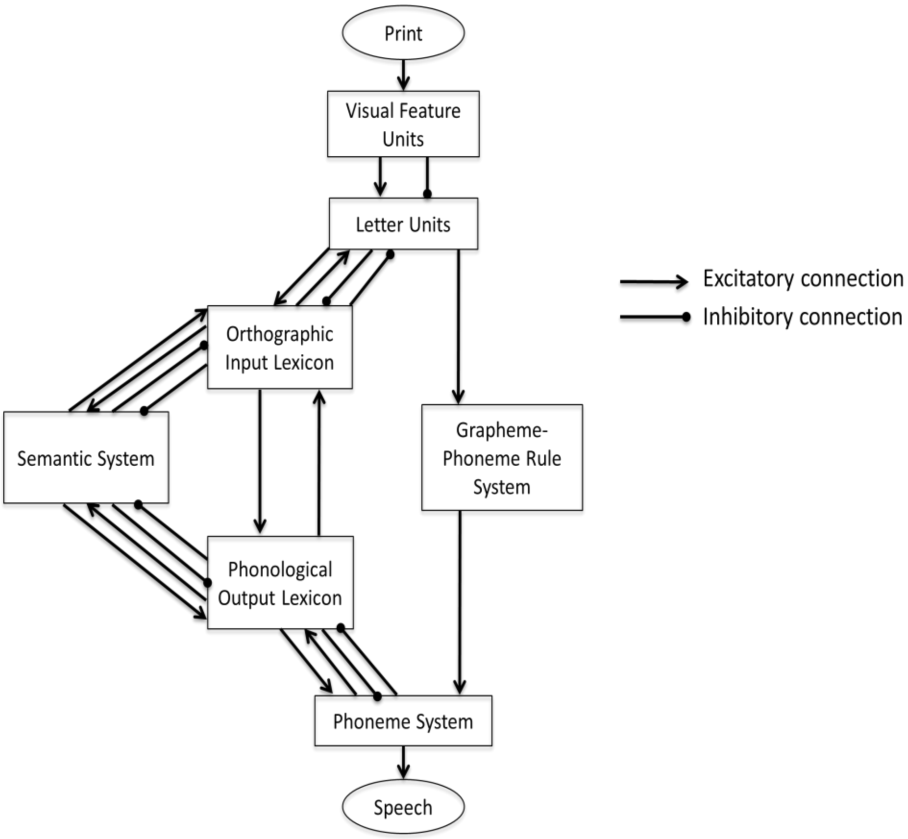

Figure 2. The DRC model. Redrawn from Coltheart et al. (2001).

Implementation of the model demonstrated that it is highly accurate at reading words and performs very well at reading nonwords, with a small error rate of 1.07% (Coltheart et al., 2001). In addition, implementation of the model showed that the DRC is able to simulate a wide range of human reading behaviours. Some of these include speed advantages for high frequency compared to low-frequency, and for regular as opposed to irregular words. In addition, implementation showed that nonwords with a large neighbourhood size are harder to reject in a recognition task, yet easier to name in a pronunciation task. Also, word reading proved to be superior to non-word reading; and word length affected the speed of nonword but not real word reading adversely (Coltheart et al., 2001). Thus, the DRC is a model well suited to simulating proficient readers' ability to name both words as well as nonwords, and demonstrates high accuracy levels for both.

In summary, the DRC is a model of reading aloud and visual word processing in which two routes operate simultaneously to arrive at the correct pronunciation of a given word. It demonstrates a high level of accuracy for both word and non-word reading, and is able to demonstrate a range of human reading behaviours. However, some phenomena associated with reading (see Coltheart, 2005; Coltheart et al., 2001), e.g., lexical decision tasks performance[2], masked priming experiments, as well as semantic processing, were not well or not at all accounted for. Some of these issues, e.g., the lexical decision task, have been addressed by other models, and are briefly discussed in the following section.

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[2] A lexical decision is a 'yes' or 'no' response to a visually or auditorily presented word, essentially specifying whether the word is a real word or a non-word. Lexical decisions are commonly indicated by means of button presses. The time taken to make a lexical decision is usually measured and used as an indication of processing speed.

2.3.1.2 The Multiple Read-out Model (MROM)

Another model that builds on the fundamental structures of the IA and attempts to account for reading in skilled adult readers was put forward by Grainger and Jacobs (1996), and is called the **Multiple Read-out Model (MROM)**. The MROM is a general IA model, and built on the concept that there is a degree of overlap between mental structures and identification processes (such as lexical decisions or reading isolated words). It is set against achieving the task to relate visual word processing with lexical decisions and perceptual processes. The model is similar to the IA in that localist lexical representations (i.e., letters) are in competition with each other. This competition is resolved through inhibitory connections, leading to the selection of the best representation (read-out). The model set out to examine whether in perceptual identification as well as lexical decision tasks, reaction time (RT) distributions can be predicted using means and standard deviations. One focus of the model is to account for the underlying processes involved in ‘yes’ and ‘no’ responses in lexical decision tasks. It was postulated that ‘no’ responses in lexical decision tasks may be controlled by extra-lexical operations and not merely by correct word identification (Grainger & Jacobs, 1996). The model made specific predictions about lexical decisions; namely that for a ‘yes’ response, two intra-lexical sources of information are involved. These two sources are the overall activity of the complete (global) lexicon (σ), as well as of the level of activation of individual units (μ). This means that a ‘yes’ response is not only initiated when the activation for the individual word reaches a certain threshold, but also when the overall activity of the global lexicon is high enough for the stimulus to be identified as being word-like. Thus, as soon as the summed activity of the global lexicon regards the input as word-like, a ‘yes’ response could be initiated. This process could take place even before the individual word unit has received sufficient activation for the word to be fully identified. For the ‘no’ response, time (t) measured from the word-onset, is treated as extra-lexical activation.

In order to compare the model to behavioural data, Grainger and Jacobs (1996) carried out a series of behavioural experiments that were followed by simulations to test whether the model was able to accurately predict experimental outcomes. For example, behavioural data (Experiments 1A-1D; Grainger & Jacobs, 1996) demonstrated that in a progressive de-masking task, during which a prime is gradually presented for longer so that it becomes visible over time, the presence of a single high frequency neighbour causes an inhibition effect. On the other hand, in a lexical decision task, but not in progressive de-masking, the presence of several neighbours with one being of high frequency, results in a facilitation effect. The model was able to accurately predict these results in a series of simulations. Similar predictions also apply to non-words. In particular, the model accurately predicts behavioural results (Experiments 2A and 2B; Grainger & Jacobs, 1996) demonstrating that in lexical decision tasks, the presence of high frequency neighbours facilitates non-word rejection, whereas an increase in the number of neighbours slows rejection of non-words, although this only applies to neighbours of low frequency.

In summary, the MROM model is able to simulate a range of data obtained in behavioural experiments, and can account for the underlying mechanism associated with ‘yes’ and ‘no’ responses to both words and non-words during lexical decision tasks. In later work, Grainger and colleagues (see 2.3.2.1) also made several attempts to account for morphological processing within a general IA framework.

2.3.1.3 The Self-Organising Lexical Acquisition and Recognition (SOLAR) model

The **SOLAR model** (Davis, 1999) is a self-organising model aiming to address a number of limitations encountered in other computational models, such as word length restrictions and the artificial contexts in which words are presented. The architecture of the SOLAR model is presented in Figure 3. As can be seen in Figure 3, the model consists of a Letter Identification System (L), a Phonological System (P), a Semantic System (S), and an Orthographic System (O). In the Letter Identification System, incoming text is analysed in terms of individual letters. The information extracted is then fed into the remaining interconnected systems O, P, and S. The model also incorporates a so-called ‘logographic’ pathway, which feeds text directly into the Semantic System, and is proposed to be most useful during sentence processing but relatively inefficient for context independent comprehension (Davis, 1999). Within the model, each module consists of a list field, responsible for chunking parts of text (e.g., *eng+lish*), and an item field, functioning as a storage facility for incoming information.

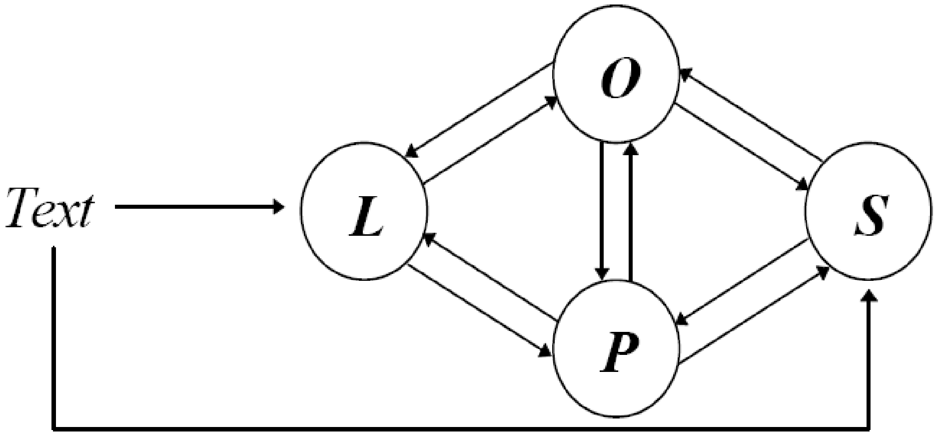

Figure 3. The architecture of the SOLAR model. Adapted from Davis (1999). L=Letter Identification System; P= Phonological System; S=Semantic System; O= Orthographic System

Once text input is received, the item field $O^{(1)}$ of the Orthographic system receives letters converted into patterns of activity from the Letter Identification System, which can subsequently be stored in the Orthographic system's list field $O^{(2)}$. In addition, there is a second Orthographic system, consisting of an item $O^{(3)}$ and a list $O^{(4)}$ field. The item $O^{(3)}$ receives the chunked input from the list field $O^{(2)}$ and in turn activates corresponding nodes in $O^{(3)}$. The list field $O^{(4)}$ is then able to activate a single node for the chunked input. This system of chunking increases the effectiveness of a memory system with limited storage capacity, and causes a reset of the $O^{(1)}$ item field (Davis, 1999). Overall, the model is interactive, interconnected, and dynamic, and attempts to model word recognition in a manner representing neural processing (Davis, 1999). Like other interactive models, the SOLAR model is not reliant on binary processing; rather, processing takes place continuously and over time. Although the model's input is serial and therefore letter by letter, processing is hypothesised to take place in parallel (Davis, 1999).

Simulations

A series of simulations tested the model's learning ability. Davis (1999) outlines that most behavioural experiments study recognition; in other words, the focus is on already learnt and acquired behaviour, rather than the learning processes itself. Thus, the initial SOLAR simulations were not based on empirical findings as they rarely focus on how word properties (e.g., length, neighbourhood) affect the learning process itself (Davis, 1999). Simulations showed that the model was able to learn words with varying length, ranging from two to seven letters. Overall, the model was faster at learning longer words (e.g., *medical*), requiring an average of only two presentations, compared to shorter words (e.g., *gem*), requiring an average of at least 6 presentations. It is possible that because shorter words (e.g., *hi*) are embedded in longer words (e.g., *his*), there is an increase in the competition between these items, resulting in the need for repeated presentations of shorter items (Davis, 1999). The ability of the model to learn longer words faster was also found for a series of words sharing letter overlap. For example, the model was able to learn the series *for, fort, forty* faster if it was presented in reverse order, i.e., with the longest word presented first. In addition, simulations showed that in the learning process, the model assigned distinct nodes for each individual word. It was also demonstrated that the network tends to be better at learning subsets of words (e.g., *for*) occurring in already learned words (e.g., *forty*) (Davis, 1999). In addition to length effects, simulations also showed that the model was able to account for word frequency effects, recognition latency effects, as well as the effects of word frequency on repetition priming in masked priming experiments (Davis, 1999).

Another important aspect of SOLAR is its ability to model the processing of polysyllabic words. Simulations demonstrated that the model was able to segment novel complex words which are semantically unambiguous (e.g., *cathole*) into their constituent words (e.g., *cat+hole*). In the simulation, due to serial processing, the node for *cat* received more activation to begin with compared to the node for *hole*. However, as processing within the SOLAR model is intrinsically parallel, both nodes received continuous activation, until they reached a certain threshold, resulting in chunking. Chunking then resulted in both nodes being reset to their original resting activation level (Davis, 1999). For ambiguous novel compounds, the process differed in as much as that chunking resulted in competition between equally plausible chunking solutions, prolonging the overall chunking process whilst searching for the optimal solution. For example, the novel compound *seatrim* could be chunked as either *seat-rim* or as *sea-trim*, both being equally valid solutions (Davis, 1999). The simulations also demonstrated that this process was influenced by a number of factors, including familiarity of the individual subsets, frequency, position and length (Davis, 1999).

In summary, the SOLAR model presents a self-organising model that is able to account for the learning of a range of mono-as well polysyllabic words without being constrained by word length. The semantic and phonological components of SOLAR, however, have not yet been implemented. Other models of visual word recognition (e.g. Plaut & Gonnerman, 2000) postulate that both phonological and semantic components are essential in distinguishing more subtle graded effects in for example, morphologically complex words. As the SOLAR model is not built to address morphology in particular, it is unclear whether the model would be able to simulate graded effects should semantic differences be demonstrated to play a role in morphological processing. However, a smaller-scale version of the SOLAR model, the recently published Spatial Coding Model of Visual Word Identification (Davis, 2010), was able to simulate a wide range of behavioural data obtained in masked priming experiments. Although the Spatial Coding Model was not designed to address morphology, phonology or semantic issues in particular, it was able to simulate a range of behavioural effects obtained in masked priming studies (e.g., effects of shared neighbourhood, frequency, prime lexicality, letter transposition, etc.) on a purely orthographic basis without taking special account of morphology, semantics or phonology. Although Davis (2010) points out that the Spatial Coding Model would most probably underestimate priming effects that can be clearly attributed to non-orthographic components, the model is nevertheless able to simulate a wide range reading behaviours solely on the basis of orthographic change.

2.3.2 Proposals for Morphological Implementations into Computational Models

As demonstrated above, the DRC, MROM and the SOLAR model simulate the behaviour of proficient, and in the case of SOLAR, learning readers well. A more recent computational model, the CDP+ (Perry, Ziegler, & Zorzi, 2007), which incorporates the lexical route of DRC but is in principle a connectionist model, is also able to model a wide range of reading behaviours. For instance, the CDP+ has an accuracy rate for reading words of 98.67%, and only made 2.87% errors for non-words. In addition, it performs well at modelling consistency effects, lengths effects and serial effects (Perry, Ziegler, & Zorzi, 2007). A recent extension of the model, the CDP++ (Perry, Ziegler, & Zorzi, 2010), is also able to simulate reading of polysyllabic words whilst also taking stress regularity into account. However, none of the models reviewed so far is specifically built to account for morphological processing, although SOLAR in particular is able to simulate the processing of both familiar and novel compounds. At present, there is no localist computational model that simulates morphological processing in proficient readers. Several proposals of how morphology could potentially be implemented in models of word processing have been made over recent years, although none of the proposals described below have been implemented in computational models. Therefore, whether any of these proposals bear significance for computational modelling remains to be demonstrated.

2.3.2.1 The Supralexical Account of Morphological Processing

One proposal of how morphological processing could be implemented was put forward by Giraudo and Grainger (2000, 2001). The **supralexical account** of morphological processing postulates that the activation of a morphemic unit is dependent upon the activation of the whole-word representation encompassing the morpheme. Thus, it is argued that in masked priming experiments, the more frequent the surface frequency of a prime word, the better it activates the target word. Essentially, the supralexical account proposes that all words sharing the same morphological root are connected via a common representation of that root. Therefore, if in masked priming experiments primes and targets share a common root, any facilitation obtained is caused by the preactivation of this common root. In this bottom-up (moving from low level form representations to higher level semantic representations) model, the representations for morphemic units are located after the whole-word units (see Figure 4). Thus, this model differs from other sublexical accounts (e.g., Taft, 1994) which postulate that the morphemic units are extracted before the whole word representations are accessed, thereby inhibiting feedback from whole-word representations to some extent (for a comparison between sublexical and supralexical account with respect to the location of the morpheme layer, see Figure 4 and Figure 5). The extraction of morphemic units allows for the morphological decomposition of complex words that only contain an apparent morphological structure (e.g., *corn+er*). The supralexical hypothesis, on the other hand, postulates that in priming experiments, only true morphological primes should facilitate target recognition. This was demonstrated by Giraudo and Grainger (2001, Experiment 2) who found that primes containing pseudo-roots (e.g., *laitue*) did not facilitate their respective derived suffixed targets (e.g., *laitier*). This finding was argued to demonstrate that morphological decomposition is not obligatory (contrary to e.g., the sublexical account proposed by Taft, 1994). Rather, the morphemic unit acts as a mediator between the whole word representation and the higher level semantic representation of a word. This means that the system is not blind to the status of the morpheme itself, but that the independent morphemic unit can actively feedback to the whole word unit as to whether a letter sequence forms a true morpheme or not.

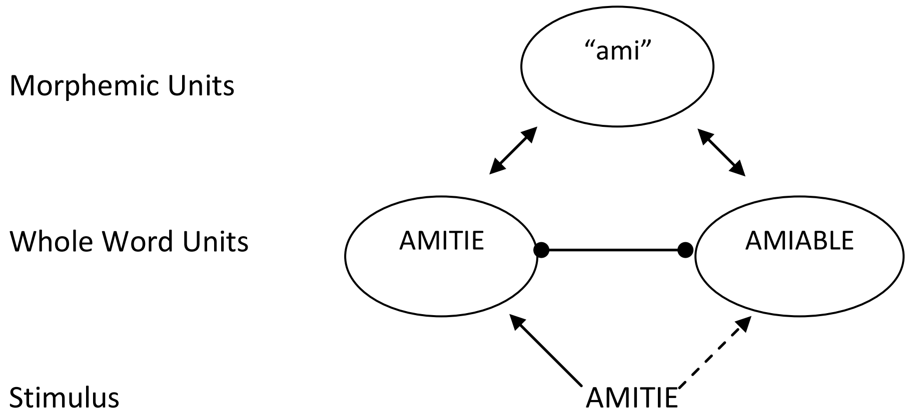

Figure 4. The Supralexical Account of Morphological Processing. Redrawn from Giraudo and Grainger (2000).

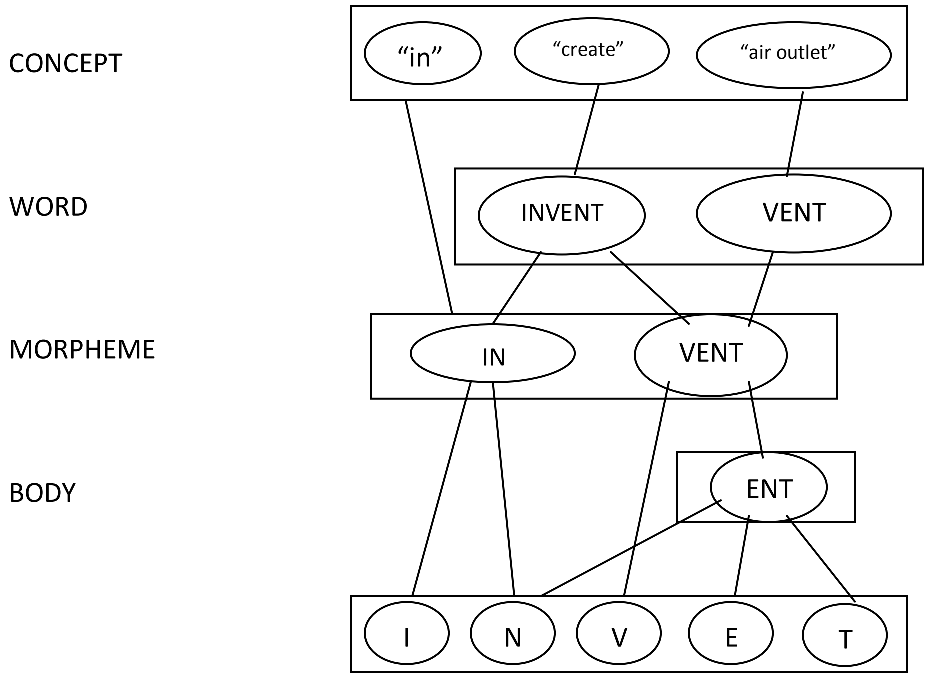

Figure 5. The interactive-activation model, with additional morpheme level (sublexical account). Redrawn from Taft (1994).

However, further experimental work by several researchers (e.g., Longtin, Segui, & Halle, 2003; Rastle, Davis, & New, 2004; see Chapter 3 for a review of evidence from behavioural studies) showed that pseudo-derived primes (e.g., corner) do indeed prime their respective targets (e.g., CORN). Consequently, such findings were argued to be better accounted for by an obligatory decomposition model such as the sublexical account of morphological processing (Diependaele, Sandra, & Grainger, 2005), rather than the supralexical model that postulates active mediation between the whole word and the semantic level by an independent morphemic unit. Subsequently, Diependaele, Sandra, and Grainger (2005, 2009) proposed several modifications to the supralexical model in order to account for priming effects obtained with pseudo-derived words. In a series of experiments, Diependaele et al. (2005) found evidence for a system being sensitive to both form (orthographic properties of complex words) as well semantics components. Thus, the system appears to be sensitive to morphological structure both when semantic and morphological properties occur together in a complex word (e.g., *walker*), and when morphological properties are presented in isolation (e.g., *corner*). Two processing systems differing in speed were subsequently proposed: a *morpho-orthographic system*, decomposing complex words into a stem and affix, independent of semantic factors (e.g., *corn+er*); and a faster *morpho-semantic system*, that, if the word is semantically transparent (e.g., *walk+er*), activates the root of a complex word early on. The morpho-orthographic system was argued to be more akin to the sublexical account, with the morpheme level feeding upwards to the whole word level. The morpho-semantic system on the other hand is representative of the supralexical account, whereby the independent morphemic unit acts as a mediator between whole word and semantic representations. The subsequently proposed **hybrid model** aims to integrate both the sublexical account (e.g., Taft, 1994) and the supralexical account (e.g., Giraudo & Grainger, 2000) into a single, unified model and allows for the morpho-orthographic level to feed upwards to the lexical level and for the morpho-semantic level to feed back to the lexical level (see Figure 6).

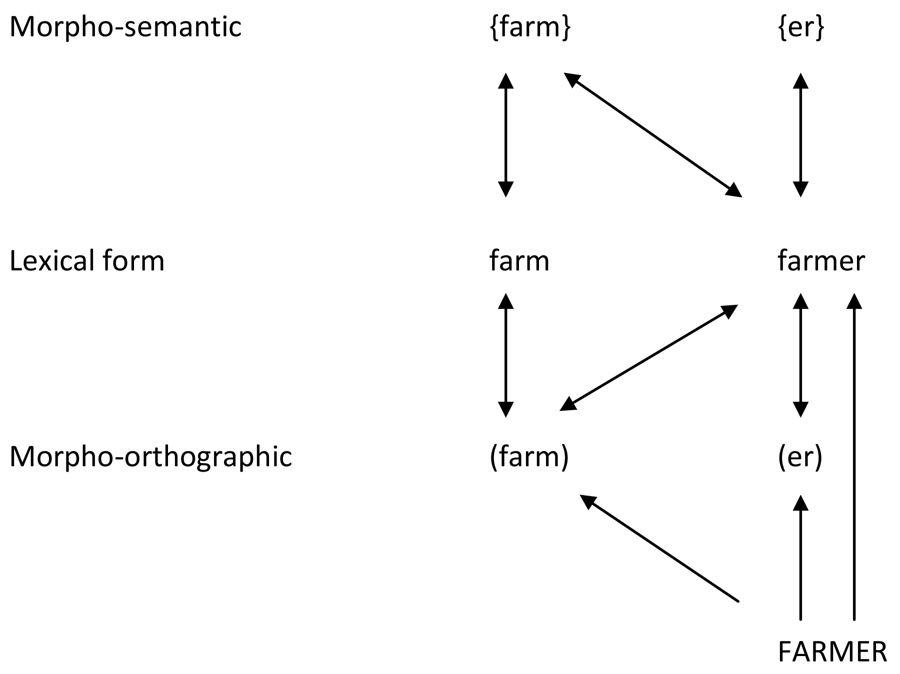

Figure 6. The hybrid model of morphological processing. Redrawn from Diependaele et al. (2009).

The faster morpho-semantic route accounts for findings that at least numerically, transparent items yield greater priming than pseudo-suffixed items (e.g., Diependaele et al., 2005; see Rastle & Davis, 2008 for a review). The principles of the hybrid model have also been demonstrated for prefixed words (Diependaele et al., 2009). Stated succinctly, the hybrid model proposes that once visual input has been received, activation spreads along the sublexical and supralexical route simultaneously and independently. However, the effects of purely morpho-orthographic processing decrease gradually as the morpho-semantic route receives feedback from the morphemic unit.

In summary, several suggestions have been made as to how models of visual word processing could potentially be modified to incorporate morphological processing. However, as discussed above, since none of these suggestions have yet been implemented computationally, it is not possible to assess to what extent the above models can account for human reading behaviour of morphologically complex words.

2.4 Distributed Connectionist Accounts of Visual Word Processing

As outlined above, one of the most defining differences between localist and distributed connectionist models is the basic assumption of how knowledge is represented. Localist models propose distinct representations for distinct meanings, whereas distributed models advocate that the identification of the correct meaning of a word is achieved through patterns of activity (as opposed to individual representations), and the summed activation of both positive as well as negative weights (Plaut, 2005). The following section provides a brief overview of two distributed connectionist accounts, demonstrating how distributed representations explain word recognition (Harm & Seidenberg, 2004) as well as morphological processing (Gonnerman et al., 2007; Plaut & Gonnerman, 2000).

2.4.1 Harm and Seidenberg's Model (HS04)

The HS04 distributed connectionist model of reading was proposed by Harm and Seidenberg (2004). The HS04 model is a computational model of reading and based on the meaning of printed words. This contrasts with earlier models (e.g., Seidenberg & McClelland, 1989) primarily interested in accounting for the translation of orthography into phonological codes. In comparison, the HS04 model attempts to explain how a *learning reader* receiving continuous input from two pathways (visual input: orth→sem; phonological input: orth→phon→sem) employs an effective mechanism to arrive at the meaning of a word (see Figure 7). This contrasts with the some of the localist models above which primarily account for visual word processing in skilled readers.

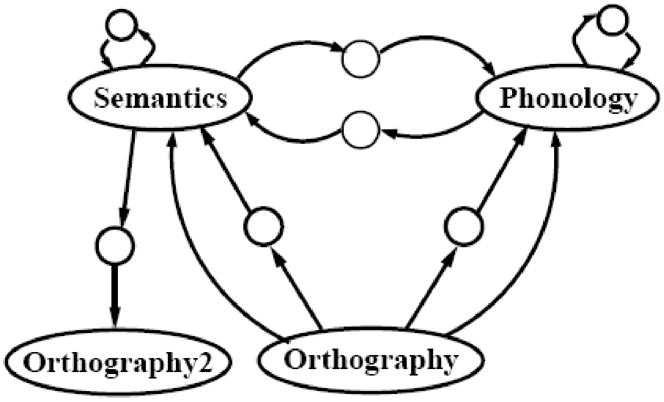

Figure 7. The HSO4 model. Adapted from Harm and Seidenberg (2004). ○ = Hidden units.

The HS04 model proposes that orthography, phonology and semantics are represented by codes, which in turn are represented by units. These units form the representations of many words. Unlike localist models, the model does not contain any lexical representations specific to words. Rather, each connection within the model has a weight, which is computed by hidden units, allowing for the encoding of complex relations between codes. There are fewer hidden units than there are words in the model, and therefore, no one single unit can account for any given single word.

The model's input is a spelling pattern from which it computes both orthographic and phonological codes. In order to simulate how the learning reader uses the two pathways to obtain the meaning of a word, the model was trained by entering 6,103 monosyllabic words and common inflections thereof. In order to encode this corpus, 1,989 semantic and 200 phonological representations were derived. All semantic and phonological representations were mapped onto 50 cleanup units, respectively. The semantic cleanup unit in turn projected back to the semantic unit, whereas the phonological cleanup unit projected back to the phonological unit (see also Figure 7) (Harm & Seidenberg, 2004). Within the model, the semantic components were mapped onto the phonological ones by means of 500 hidden units, enabling feedback between the two. Once the model was fully trained, it was able to form 'attractors'. Attractors were argued to be able to repair degraded or only partially available information; they can also pull degraded information towards more established representations (Harm & Seidenberg, 2004). Attractors are a common feature in distributed connectionist models, as they contribute to the overall stability of connectionist models, and help the system to combat noise, as well as effectively deal with degraded or damaged input (Plaut, 2005).

Overall, Harm and Seidenberg's (2004) model demonstrates that semantic activation builds up over time, rather than instantaneously, making use of all available modes of input (orth→sem and orth→phon→sem). With repeated training cycles, both input pathways of the models are learning to accurately predict the majority of words. In the early stages of learning, however, the orth→phon→sem is the faster of the two pathways, demonstrating the primacy of the phonological route in the beginning reader. As the model develops, the orth→sem pathway is the one that continues learning, and is crucial in disambiguating homophones. The most effective and fastest output is achieved if the model makes use of both pathways, compared to each pathway in isolation.

The model was able to simulate a range of behavioural data. In a series of 19 simulations, Harm and Seidenberg (2004) demonstrated a range of phenomena. For example, the model is able to produce the pronunciation of nonwords to an accuracy of 93%, providing they were derived from regular real words. However, production of irregular nonwords was less precise with a correct output of 84%. In addition, the model is also able to simulate plural inflection as well as past tense forms of verbs, and is thus capable of producing morphological regularities. However, the model was more accurate in determining the past tense (100% accuracy) compared to the plural inflections of words (82% accuracy).

Although the model does not specifically focus on the processing of more morphologically complex words, and all words entered to train the model were monosyllabic, Harm and Seidenberg (2004) addressed morphology to a limited extent in relation to nonwords. In the second simulation phase, semantic representations included both plural forms (e.g., *goats*), as well as simple past forms of verbs (e.g., *baked*). It was then tested whether the model would be able to activate morphological features in nonwords. It was shown that the model was able to activate plural and past tense features over 88% of the time, and where such features were falsely activated they tended to be homophones (e.g., *dere* instead of *dear*). Thus, the model was able to identify some morphological features correctly, with limitations imposed by homophones, although the model cannot provide an account of how the learning reader develops representations for morphological features. The main purpose of the model, however, was to address the question of how the two pathways (orth→sem and orth→phon→sem) work together to determine the meaning of words, and it was demonstrated by Harm and Seidenberg (2004) that both pathways work simultaneously to arrive at a word's meaning, and that both pathways are involved in learning. However, several issues, such as the contribution of the pathways in pronunciation as well as how the processing of multisyllabic words can be incorporated into the model, have yet to be addressed.

2.4.2 A Distributed Connectionist Account of Morphological Processing

An account of how distributed connectionist systems may incorporate morphological processing was put forward by Plaut and Gonnerman (2000) and Gonnerman et al. (2007). In general, the distributed connectionist account of morphological processing postulates that morphological representations are the result of mappings between orthography (form) and meaning (semantics), whereby reoccurring morphological components in words (e.g., the ending *–er* as a nominalisation suffix) tend to be mapped onto meaning representations (Plaut & Gonnerman, 2000). Thus, any behavioural evidence obtained should reflect the degree of overlap between orthography and semantics. Therefore, in priming experiments it would be predicted that the more a prime and target share overlap between form and meaning, the greater the priming magnitude that will be obtained. Plaut and Gonnerman (2000) put forward five computational principles of connectionist modelling, implemented in their network to simulate morphological processing. These are: 1) Distributed representations; each unit is involved in representing a range of items; there is not direct one-to-one mapping of meaning. 2) Systematicity; similar types of input will inevitably produce similar patterns of output, indicating that similar inputs will produce similar weights, which in turn lead to predicable outputs. 3) Learned internal representations; this relates to the fundamental distributed assumption of hidden units mediating between input and output patterns carrying learned representations between form and meaning. 4) Componentiality; this is particularly relevant to morphology, whereby morphemes may form discrete parts of words that can be present or absent (e.g., affixes). In connectionist models, componentiality allows the network to represent these morphemes in graded fashion, either as transparent (e.g., learner), opaque (e.g., corner), or intermediate (e.g., dresser). 5) One system; all aspects of processing are dealt with within one and the same system. This indicates that in distributed connectionist modelling, the same set of weights must know how to account for all aspects of processing and knowledge. This poses particular problems for opaque items, which may be less accurately presented by the system (they may be subject to overriding principles from transparent mappings), depending on the nature of the task. In a series of two simulations, Plaut and Gonnerman (2000) attempted to account for how a distributed network can model comprehension of morphologically complex words in a morphologically rich language such as Hebrew, and a more morphologically impoverished language such as English. The network comprised of three layers, in which 30 orthographic units were connected to 300 hidden units, mapping on to 50 semantic units. Overall, the model contained 24,350 connections. Morphology in the network was represented in terms of stems and affixes which were coded as having fully transparent, intermediate, distant, or fully opaque meanings. Subsequently, two artificial languages akin to Hebrew and English were created, each consisting of 1200 words, containing words varying in the degree of their semantic transparency. The network was fully trained on both languages. Simulations showed that the network was much faster at learning the morphologically rich than the impoverished language, requiring only half the number of sweeps through the entire word corpus (Plaut & Gonnerman, 2000). In terms of modelling how the distributed connectionist network behaves during masked priming conditions, it was demonstrated that overall, reaction times (RT) were faster for the morphologically rich language, argued to be due to the network being more morphologically structured. However, priming effects were greater for the impoverished language, and there was considerably less priming as transparency decreased across the conditions. It was argued (Plaut & Gonnerman, 2000) that these results suggest that in impoverished languages, opaque items (e.g., corner) containing morphemes which also occur in other contexts (e.g., in transparent items such as teacher), are able to freely vary and are less constrained by the other contexts in which these morphemes occur also. Therefore, the mere fact that an opaque prime contains morphemes also occurring in other contexts does not exert a significant influence on the subsequently presented target. This, however, is not the case for morphologically rich languages, in which each morpheme is more strongly influenced, and thus constrained, by how morphemes are represented across the entire language. A further simulation confirmed this trend by demonstrating that significant priming for more opaque items could only be obtained for the morphologically rich language (Plaut & Gonnerman, 2000). It was thus argued that in essence the distributed connectionist account of morphological processing is that of a graded one and refers to learned associations between orthography and semantics, and is therefore highly sensitive to the similarities between these two measures. This means that within a distributed connectionist account, individual morphemes are not encoded as separate entities; rather, the varying regularities between form, meaning, as well as phonology, are encoded in such a manner that their summed net activity activates relevant morphological characteristics within words (Gonnerman et al., 2007). This was confirmed in a series of behavioural experiments by Gonnerman et al. (2007) demonstrating that the degree of orthographic, semantic, as well as phonological overlap between primes and targets contributes to the graded nature of morphological processing. These experiments showed that the greater the similarity between both semantics and phonology (*marked-mark* as opposed to *market-mark*) the greater the priming obtained. In summary, it can therefore be said that the distributed connectionist account does not view morphemes as individual meaning-bearing units that can be coded for as separate entities (Gonnerman et al., 2007); rather, morphology is the result of the interaction between orthography, semantics, as well as phonology.

2.5 Summary

This chapter has provided an overview of some of the most important computational models of visual word processing and has drawn on suggestions for how morphological processing may be implemented in computational models. Crucially, this chapter has also demonstrated different approaches to word processing, with a localist framework on the one hand, and a distributed connectionist approach on the other. The debate between these two branches of modelling word processing is also evident in their approach to morphological processing, with localists arguing for distinct node representations for morphemes, allowing for segmentation of any complex word containing an apparent morphological structure, and distributed connectionists advocating morphology as the result of the summed activation of orthography, semantics, and phonology. The commencing chapter provides an overview of behavioural evidence for morphological processing within the framework of experimental psychology.

Chapter 3

Evidence for Morphological Processing from Experimental Psychology

3.1 Introduction

As demonstrated in Chapter 2, a range of models of word processing have attempted to provide an account of how morphologically complex words are comprehended. Some connectionist models advocate a distributed, graded account of morphological processing, with no separate locus of representation for morphology (e.g., Gonnerman, Seidenberg, & Andersen, 2007), whereas other models (e.g., Coltheart et al., 2001) advocate a more localist account of word processing that, when applied to morphology, argues for distinct representations of morphemes. The debate surrounding morphological processing within the context of modelling is also mirrored in the experimental literature. Here, contrasting behavioural evidence continues the argument surrounding the degree of semantic contribution when morphologically complex words are processed.

Pioneering work to study morphological processing within the framework of experimental psychology was carried out by Taft and Forster (1975, 1976). In a series of behavioural experiments, which were later ratified employing more contemporary methodologies (Taft, 1994), it was proposed that visually perceived polymorphemic words undergo a process of morphological decomposition. This means that prior to the lexical representation of a word being accessed, a morphologically complex word is analysed in terms of its constituent morphemes.

For example, complex words such as *walker* would be decomposed into *walk* and –*er*. Thus, a complex prefixed word such as *rejuvenate*, it was argued, would be decomposed prior to accessing its lexical representation. By means of this decomposition process, the lexical representation would be stored as *juvenate*, rather than *rejuvenate*, aiding a more rapid access to the word (as opposed to searching for this particular entry amongst all words beginning with re-). This initial account of morphological processing was expanded with the Basic Orthographic Syllabic Structure (BOSS) (Taft, 1979) account of lexical representation in the mental lexicon. The BOSS principle proposes that within the lexicon, complex words are syllabified to such a degree that it does not disrupt the morphological structure of a word. For example, words such as *lantern*, which would have traditionally been regarded as being syllabified as *lan-tern*, are represented in a way preserving their morphological structure, e.g., *lant-ern.* Thus, lexical storage of complex words was proposed to be in terms of their orthographic as well as morphological factors, thereby supporting the account of morphological decomposition based on the orthographic (as opposed to phonological) features of words. These first experiments paved the way for several influential studies to be conducted in experimental psychology, further exploring how proficient readers process morphologically complex words. There are several experimental approaches to studying morphology within psychology, and some of these are reviewed below.

3.2 Evidence for Morphological Processing in Early Visual Word Recognition

3.2.1 Evidence from Masked Priming Experiments

Several studies have made use of a masked priming paradigm (Forster & Davis, 1984) to study morphological processing in very early visual word processing. In masked priming research, the prime is presented for such a short time that it cannot be consciously perceived. In most experiments, the prime is preceded by a pre-mask, usually a series of hash marks (e.g., #######), which remains on the computer screen for 500ms. Immediately after, the prime appears for a short duration, which in masked priming experiments is often less than 50ms. The prime is then masked by the target which is presented immediately after the prime, and to which a lexical decision (i.e., a 'yes' or 'no' response usually indicated by a button-press) has to be made.

A number of studies have used the masked priming methodology to explore to what extent morphologically transparent as well as morphologically opaque primes prime their respective targets. Morphological transparency refers to morphologically complex words that can be parsed into a free standing morpheme (a stem) and a corresponding suffix. One such example is the word *cleaner*, which can be parsed into the stem *clean* and the suffix *–er*. A *cleaner* therefore is someone who *cleans*. Thus, morphologically transparent items are also semantically related. They are also referred to as semantically transparent complex words (see Rastle et al., 2004). Opaque items on the other hand, although also parsable into a free standing morpheme and an affix, are not semantically related and only share a pseudo-morphological relationship. For example, the word *corner* can be parsed into *corn* and *–er*, although a *corner* is not someone who corns, but a point in space where two lines converge. However, both *corner* and *corn* can be argued to have etymological roots in the French word *corne* (meaning ‘horn’, pertaining to animals) dating back to the 13th century (Online Etymology Dictionary, 2011). As outlined by Longtin et al. (2003), many such etymological relationships exist between opaque prime-target pairs. However, their surface morphological relationship is ‘misleading and is not a reflection of their synchronic structure or diachronic formation’ (p. 316). A more detailed explanation of how transparent and opaque prime-target pairs differ can be found in Longtin, Segui, and Halle (2003) and Rastle, Davis, and New (2004). In addition to transparent and opaque pairs, some (e.g., McCormick, Brysbaert, & Rastle, 2009; Rastle et al., 2004), but not all (e.g., Feldman, O'Connor, & del Prado Martin, 2009), masked priming studies exploring morphological priming have also implemented orthographic form control items, against which the magnitude of morphological priming is measured. For example, the prime-target pair *wrench-WREN* share neither a semantic (*wrench* indicating a sudden twist, and *wren* being a garden bird) nor a morphological relationship (*-ch* is not a morpheme in English). Nevertheless, prime and target share substantial position invariant letter overlap, and the target is fully contained within the prime, akin to transparent and opaque items. Thus, items such as *wrench-WREN* are ideal orthographic controls.

Making use of masked priming procedures, Longtin et al. (2003) examined the extent of morphological priming in French, using transparent (e.g., *gaufrette-*

GAUFRE; wafer-WAFFLE), opaque (e.g., *fauvette-FAUVE;* warbler-WILDCAT), and orthographic control (e.g., *abricot-ABRI;* apricot-SHELTER) prime-target pairs as described above. In addition, the researchers also introduced pseudo-derived prime-target pairs, whereby the target is fully embedded in the prime and the remaining letter sequence forms an existing morpheme (as is the case for opaque items). However, the items were selected such that opaque pairs shared an etymological relationship, whereas in the pseudo-derived condition, primes and targets never shared an etymological relationship (e.g., *baguette-BAGUE;* little stick- RING). Using a prime duration of 46ms, Longtin et al. (2003) showed that all pairs containing morphologically complex primes, irrespective of their semantic or etymological relationship, significantly facilitated the recognition of their respective targets (transparent 38ms; opaque 43 ms; pseudo-derived 26ms). In contrast, this was not the case for orthographic form control pairs. Here, the non-morphological prime resulted in inhibition of the target (-26ms). These findings suggests that the priming effect obtained with morphologically complex primes can be mainly attributed to morphological effects and cannot be fully explained by shared orthographic overlap or semantic similarity alone.

Similar results were obtained in English by Rastle et al. (2004). The researchers used transparent (e.g., *viewer-VIEW*), opaque (e.g., *whisker-WHISK*), and orthographic form control (e.g., *freeze-FREE*) prime-target pairs to establish whether significant priming with morphologically complex primes can be obtained regardless of the semantic relationship between primes and targets. Using an even shorter prime duration (42ms) than Longtin et al. (2003), they obtained a similar priming magnitude for both transparent (27ms) as well as opaque (22ms) pairs. For orthographic form control pairs, the priming effect obtained was negligible (4ms) (see Table 1). These results were interpreted to provide further evidence that in early visual word processing, a word is rapidly decomposed into its apparent morphological constituents of stem and affix.

Table 1. Mean Reaction Time for Rastle et al. (2004).

	Transparent	**Opaque**	**Form**
Related prime	570	598	635
Control prime	597	620	639
Priming effect	**27**	**22**	**4**

It was also argued that this process takes place irrespective of the semantic relationship between the complex word and the stem itself. Thus, in early visual word processing, complex words such as *corner* are treated akin to words such as *walker*. It would therefore appear that the visual word processing system does not take account of semantic factors until later in the recognition process. One study proposing such an account of late semantic contribution is a time course study conducted by Rastle, Davis, Marslen-Wilson, and Tyler (2000). In two experiments, the orthographic (O), morphological (M), and semantic (S) relationship between primes and targets was manipulated (pairs were related ‘+’ or unrelated ‘-‘), as shown in Table 2. In Experiment 1, three groups of participants were tested at SOAs of 43ms, 72ms, and 230ms, respectively. Across all SOAs semantically transparent derived items (+M+S+O) produced consistent priming over and above other items, and a priming effect comparable to that of the identity condition. In addition, there was also robust facilitation at 43ms, but not at any other SOAs, for semantically opaque items (+M-S+O), indicating that in early visual word processing, morphological decomposition may occur in the absence of semantic transparency.

Table 2. Stimuli example for Experiments 1 and 2 of Rastle et al. (2000). M=morphological, O=orthographic, S=semantic, '+'=related, '-'=unrelated.

	Condition	Example
Experiment 1	+M+S+O	departure-DEPART
	+M-S+O	apartment-APART
	-M+S-O	cello-VIOLIN
	-M-S+O	electrode-ELECT
	Identity	cape-CAPE
Experiment 2	+M+S+O	adaptable-ADAPT
	-M+S+O	screech-SCREAM
	-M+S-O	pygmy-DWARF
	-M-S+O	typhoid-TYPHOON
	Identity	church-CHURCH

In Experiment 2, again, participants were tested at SOAs of 43ms, 72ms, or 230ms. Results demonstrated that semantically related items (-M+S-O, and -M+S+O) only produced consistent priming at 230ms, suggesting that for semantically related primes to facilitate target recognition, they must be perceivable. In contrast, morphologically related items (+M+S+O) produced a consistent priming effect at all SOAs. Orthographic relatedness between primes and targets, however, did not influence that amount of priming at any SOA[3]. Both Experiment 1 (see Figure 8) and 2 suggest that morphologically derived primes affect target recognition both when primes are and are not consciously perceivable. For short SOAs, this finding cannot be attributed to either semantic or orthographic overlap, again suggesting that it is

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[3] Taft and Kougious (2004) comment that the failure to obtain priming with orthographically related pairs that also share a meaning relationship (e.g., screech-SCREAM) may be due to the haphazard nature of the items selected. Some items were matched on onset letter overlap (e.g., frost-freeze), some at the offset (e.g., hotel-motel, fondle-handle). Taft and Kougious (2004) demonstrate that there is robust priming for monomorphemic items sharing onset subunits as long as they share a semantic relationship (e.g., viral-VIRUS but not futile-FUTURE).

the morphologically complex status of the prime alone that facilitates recognition of its respective target.

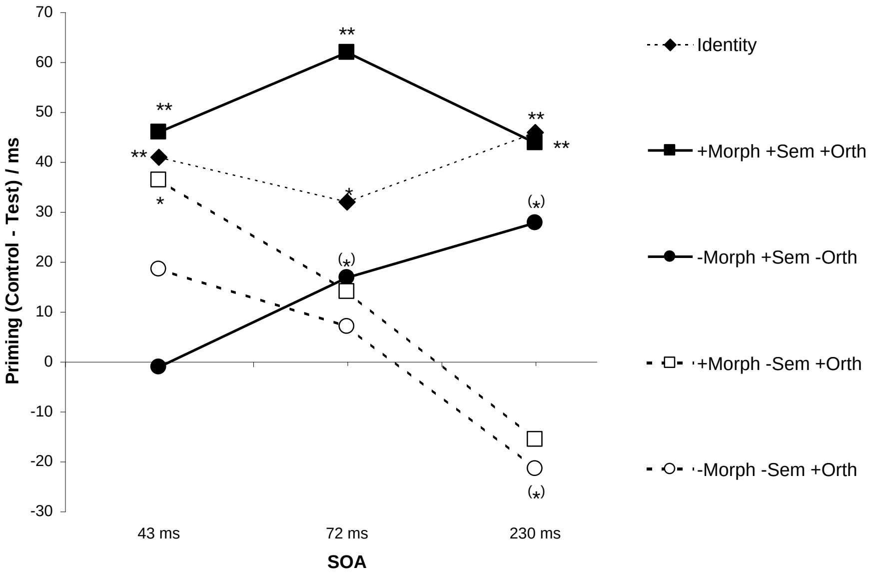

Figure 8. Experiment 1, adapted from Rastle et al. (2000). Priming effects across SOAs of 43, 72, and 230ms. **p<0.01 (subjects and items); *p<0.05 (subjects and items); (*) significant by subjects or items.

Exploring the extent to which semantic factors contribute to morphological processing in early visual word processing further, Marslen-Wilson, Bozic, and Randall (2008) selected morphologically complex primes that varied in the degree of semantic relatedness to their respective targets. In six conditions, the researchers manipulated both morphological as well as semantic relatedness. The conditions included prime-target pairs as follows:

(1) only orthographically related (e.g., *scandal-SCAN;* -M-S+O)

(2) only orthographically and morphologically related (e.g., *archer-ARCH*; +M-S+O)

(3) orthographically and morphologically related, somewhat semantically related (e.g., *barely-BARE*; +M midS +O)

(4) only somewhat semantically related (e.g., *attach-GLUE*; -M midS –O)

(5) related on all three criteria (e.g., *bravely-BRAVE*; +M+S+O)

(6) only purely semantically related (e.g., *accuse-BLAME*; -M+S-O).

The authors made use of an incremental masked priming technique, although in contrast to Rastle et al. (2000), the prime never became fully visible. Specifically, in three separate studies (Experiment 1a-c) the stimulus onset asynchrony was 36ms, 48ms, and 72ms, respectively. Results demonstrated that in comparison with conditions containing no morphological relationship between items (conditions 1, 4, and 6), prime-target pairs that shared a potential morphological relationship (conditions 2, 3, and 5) yielded robust priming effects across all three SOAs, irrespective of the degree of their semantic relatedness. In fact, there was no significant difference in the priming magnitude obtained between the morphologically related conditions. Further, this priming magnitude was not affected by SOA (although there was a numerical upward trend with increasing SOA). These results were argued to be a clear demonstration that morphological priming and semantic priming are distinguishable. Although purely semantically related items (condition 6) yield a medium priming effect (19ms), morphological decomposability appears to be the most significant predictor of priming magnitude.

In contrast, a study by Feldman, Soltano, Pastizzo, and Francis (2004, Experiment 3) examining the role of semantic transparency in morphological processing did not yield comparable results. In a masked priming lexical decision task, using an SOA of 83ms, the researchers compared prime-target pairs that were semantically transparent (e.g., *according-ACCORDANCE*), and semantically opaque (e.g., *accordion-ACCORDANCE*), with morphologically complex orthographic controls (e.g., *dictation-ACCORDANCE*). However, no effect of prime status on reaction latencies was found, not even against the control condition. Only when target family size was taken into account, a trend emerged for transparent items to yield more priming than opaque items, although this trend did not reach significance. It is noteworthy though that the items in the Feldman et al. (2004) study differ to the body of evidence presented above. The study did not contain a purely orthographic, non-morphological baseline against which the effects of semantic transparency in morphological processing could be measured. Also, the targets used by the researchers were complex derived or pseudo-derived words, and not free stems. Thus, both primes and targets were complex words. Similar findings for derived prime-target pairs have also been obtained by Marslen-Wilson, Tyler, Waksler, and Older (1994; see below for a more detailed description) in a cross-modal priming study. The authors demonstrated that derived primes do not prime derived targets, irrespective of semantic transparency.

Recent research has argued that the evidence for semantically independent morpho-orthographic segmentation in early visual word recognition (Longtin et al., 2003; Marslen-Wilson et al., 2008; Rastle & Davis, 2008; Rastle et al., 2004, see above) is robust, and some evidence suggests this is also the case in the face of common orthographic alterations that take place during derivational and inflectional processes. Such orthographic changes have as consequence that the morphologically complex word cannot be parsed perfectly into a stem and affix (e.g., *serenity* cannot be parsed into *serene + ity*, but parses into *seren + ity*). In a series of masked priming experiments with an SOA of 42ms, McCormick, Rastle, and Davis (2008) demonstrated that for words that drop the letter 'e' (e.g., *adore → adorable*), share a letter 'e' (e.g., *love → lover*), or duplicate a consonant (e.g., *drum → drummer*) at the morpheme boundary, there is robust facilitation of target recognition. Morphologically complex prime-target pairs with these orthographic changes were compared to orthographic form controls, as well as morphologically complex pairs that could be parsed perfectly (e.g., *walk+er*). The authors showed that there was no difference in the magnitude of priming between those morphologically complex words that could and those that could not be perfectly parsed into a stem and affix. In addition, this robustness was further demonstrated for prime-target pairs that were not semantically related but underwent the same orthographic changes (e.g., *committee–COMMIT*; *badger–BADGE*; and *fetish–FETE*) as semantically related items. Again, these data suggest that it is the morphological status of the prime alone that results in significant target facilitation, irrespective of semantic transparency or parsability thereof.

Although, as outlined above, there is a growing body of support for morpho-orthographic segmentation, not all studies exploring this issue have come to the conclusion that early morphological decomposition is mainly influenced by the morphological status of the items. For example, in a recent study Feldman, O'Connor and Moscoso del Prado Martin (2009) compared the magnitude of priming for transparent (e.g., *beeper-BEEP*) and opaque (e.g., *battery-BATTER*) prime-target pairs. Using an SOA of 50ms, the authors found robust facilitation for transparent morphological items (30ms), and negligible facilitation for opaque morphological items (4ms). The results were interpreted as posing a challenge to the form-then-meaning account prevalent in the psycholinguistic literature, as they demonstrate that semantically transparent items yield significantly more facilitation compared to opaque items. However, the design of the experiment did not provide a non-morphological orthographic control baseline measure (contrary to the growing body of evidence cited above) against which both transparent and opaque priming effects could be measured. It is therefore difficult to argue that the results can be confidently attributed to semantic transparency rather than morphological status. Despite this, a recent line of evidence is moving the discussion surrounding the 'form-then-meaning' account of morphological processing towards an account of *graded* morphological processing. Diependaele, Duñabeitia, Morris, and Keuleers (2011; Experiment 1) made use of the design employed by Rastle et al. (2004) but used an SOA of 53ms, which is a longer SOA than typically used in the morpho-orthographic work. They demonstrated that English native speakers show most priming for transparent items (36ms), and least for form items (1ms). Opaque items produced an effect of a magnitude (15ms) that is between that of the transparent and form condition. However, only the transparent condition significantly differed from the form condition with respect to priming magnitude (see Table 3). A similar pattern of results was obtained with an SOA of 70ms by Rastle et al. (2000)

Table 3. Mean Reaction Times for Diependaele et al. (2011), Experiment 1.

	Transparent	**Opaque**	**Form**
Related prime	592	612	636
Control prime	628	627	637
Priming effect	**36**	**15**	**1**

With the publication of an arguably large data set (Experiment 1, 2, and 3 combined), Diependaele et al. (2011) argue that semantic effects on early morphological processing are a reality, rather than a by-product of methodological differences between studies as proposed by Rastle & Davis (2008).

In summary, there has been considerable evidence from masked priming experiments in a favour of a morpho-orthographic decomposition account in early visual word recognition. Several studies, as outlined above, have obtained significant priming for both transparent and opaque morphological items, irrespective of the semantic relationship shared between these items. There is evidence to suggest that in early visual word processing, morphological decomposition is guided by a purely orthographic principle, leading to the decomposition of any item with an apparent morphological structure (Rastle et al., 2004). However, more recent research has challenged this account, arguing for a graded account of morphological processing, attributing a moderate role to semantic factors in early visual word processing.

3.2.2 Evidence for Morphological Processing from Cross-Modal Priming Studies

Further evidence for morphological processing has been obtained with studies making use of cross-modal priming methodologies. In cross-modal priming, primes and targets are presented in different modalities. Primes are often presented auditorily, and played through headphones, whereas the targets, to which lexical decision have to be made, tend to be presented visually on a computer screen. Cross-modal priming studies have provided additional support for the notion that morphologically complex items are decomposed into a stem and affix. However, such effects have often only been substantial when semantic factors were taken into account. In Dutch for example, Diependaele, Sandra, and Grainger (2005) tested participants on a cross-modal lexical decision task, whereby half the targets were presented visually, and half auditorily. The primes, on the other hand, were always presented visually (SOA 53ms). Prime types were: (1) a derivation of the target (e.g., *domheid-DOM*; stupidity-STUPID), (2) semantically unrelated orthographic controls (e.g., *dominee-DOM*; preacher-STUPID), and (3) monomorphemic unrelated controls (e.g., *paprika-DOM*; pepper-STUPID). In addition, a further three prime types were constructed which were pseudo-derived, i.e., the prime consisted of a pseudo-root as well as a pseudo-affix, and was not semantically related to the target (e.g., *branding-BRAND*; surf-fire). For pseudo-derived items, corresponding orthographic control and unrelated primes were constructed as well. Findings showed that for derived primes, facilitation was reliable compared to orthographic as well as unrelated primes, both when targets were presented visually and auditorily. For pseudo-derived primes, however, weak facilitation could only be obtained when targets were presented visually. There was no facilitation when primes were presented auditorily. These results seem to indicate that cross-modally, only transparent pairs bearing a semantic relationship between prime and target yield significant facilitation[4].

Other cross-modal priming studies have obtained similar findings. In a series of six experiments, Marslen-Wilson, Tyler, Waksler, and Older (1994) made use of cross-modal immediate repetition priming. Primes were presented auditorily, followed by a visually presented target word to which a lexical decision had to be made. The semantic, morphological and phonological relationship of prime-target pairs was manipulated across all experiments, so that a range of transparent (e.g., *friendly-FRIEND*), opaque (e.g., *casualty-CASUAL*) and control items (e.g., *tinsel-TIN*) were presented. Several other conditions were presented as well, including suffixed and prefixed prime - target pairs (e.g., *confession-CONFESSOR, unfasten-REFASTEN,* respectively), and pairs whereby the stem functioned as prime (e.g., *strain-RESTRAINT*). Overall, the results demonstrated that in cross-modal priming, with auditorily presented primes, robust priming can only be obtained when the prime and target share a morphological as well as semantically transparent relationship. Opaque pairs, regardless of their morphological status, did not yield reliable priming effects. Interestingly, no priming could be obtained with suffix derived primes and targets (e.g., successful-SUCCESSOR), irrespective of semantic

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[4] The priming methodology applied in this study differed from other masked-priming procedures. Diependaele et al. (2005) inserted a pseudo-random backward mask after each prime presentation consisting of a string of consonants (e.g., WCXPLSTHNZD). Diependaele et al. (2005) point out that the insertion of backward masks in masked priming studies have been argued to cause interference effects at low-letter coding stages, leading to slower prime activation (see Grainger, Diependaele, Spinelli, Ferrand, & Farioli, 2003).

transparency (see also Feldman et al., 2004). However, prefixed pairs (e.g., *unfasten-REFASTEN*), as well as prefix-suffix (e.g., *distrust-TRSUTFUL*) and suffix-prefix (e.g., *judgement-MISJUDGE*) pairs were shown to yield significant priming in the magnitude of 30ms. This somewhat surprising pattern of results was interpreted as demonstrating that two semantically transparent derived items, such as *government* and *governor,* will attempt to access the same lexical region. In their attempt, they inhibit each other so that the same stem will not be activated for two competing lexical entries. Prefixed items on the other hand appear not to compete semantically for the shared lexical entry, and thus lead to significant facilitation of each other.

Further support for the notion that semantic factors play a role in cross-modal morphological priming was put forward by Meunier and Longtin (2007). In a cross-modal task akin to the methodology employed by Marslen-Wilson et al. (1994), several French pseudo-word prime types were constructed. These included (1) non-interpretable illegal morphological pseudowords (e.g., *graragité-GARAGE*), (2) morphologically complex interpretable pseudo-words (e.g., *rapidifier-RAPIDE*), (3) morphologically complex synonym pseudo-words (e.g., *cuisineur-CUISINE*), and (4) non-morphological pseudo-words (e.g., *rapiduit-RAPIDE*). All conditions were compared to existing derived primes (e.g., *garagiste-GARAGE*) as well as unrelated control primes (e.g., *diversion-GARAGE*). A clear priming pattern emerged, demonstrating that interpretable morphologically complex pseudo-words reliably and consistently prime their respective targets to a degree comparable to that of existing derived words. However, the mere presence of a suffix in a pseudo-word (see (1)) does not result in priming if the resulting word cannot be semantically interpreted. On the other hand, the priming effect obtained with pseudo-words cannot be explained by mere orthographic overlap, as non-morphological pseudo-words (see (4)) did not yield significant priming effects. Thus, this effect may have to be interpreted within a framework of rapid morphological decomposition that takes account of semantic factors.

Taken together, these results suggest that in cross-modal priming, semantic transparency between primes and targets appears to be a crucial factor determining the extent to which morphologically complex primes facilitate target recognition. This priming effect cannot be solely accounted for by the morphological status of the prime or orthographic overlap between prime and target.

3.3 Evidence for Morphological Processing of Irregularly Inflected Verbs

3.3.1 Masked Priming Effects with Irregularly Inflected Primes

As outlined in Chapter 1, the majority of English verbs are regularly inflected, and only about 150 verbs are inflected using irregular forms. As described, these irregular forms can be grouped into more regular sub-categories. Studies into morphological processing of irregular verbs have provided some indication for masked priming effects of irregularly inflected verbs (e.g., Meunier & Marslen-Wilson, 2004, Experiment 2; Pastizzo & Feldman, 2002). Recent research has put forward some compelling evidence for priming effects of irregularly inflected verbs. In a series of three experiments using an SOA of 42ms, Crepaldi, Rastle, Coltheart, and Nickels (2010) showed that irregularly inflected verb forms (e.g., *fell*) facilitate their related stems (e.g., *FALL*) over and above the effects of orthographically related pairs (e.g., *fill-FALL*) and control pairs (e.g., *hope-FALL*). In addition, Experiment 2 demonstrated that the priming effect of irregularly inflected verbs does not generalise to word pairs that only follow a similar orthographic, but not morphological pattern (e.g., *book-BAKE* akin to *shook-SHAKE*). Rather, it appears that only genuine irregular verb-forms produce robust priming of their related stems, in spite of limited orthographic overlap in some cases (e.g., *bought-BUY*). In Experiment 3, Crepaldi et al. (2010) introduced further orthographic controls to test for the robustness of this effect. By introducing a carefully matched orthographic (e.g., *swamp-SWEAR*) as well as unrelated (e.g., *pinch-SWEAR*) baseline, the researchers demonstrated that irregularly inflected primes (e.g., *sworn*) prime their related stem (e.g., *SWEAR*) more than pseudo-irregular primes prime their respective targets (e.g., *born-BEAR*). These surprising results cannot be accounted for by the morpho-orthographic segmentation process proposed by Rastle, Davis, and New (2004), because of the absence of a shared stem between prime and target and partly because of the above mentioned lack of orthographic overlap between prime and target. Thus, the authors took the results as an indication for the existence of a second locus of early morphological priming within the word recognition system. They postulated that irregularly inflected primes such as *fell* activate the infinitive form *fall* at the morpho-orthographic stage**.** This activation in turn activates *fall* at the lemma level. The subsequently presented target *FALL* also activates this lemma, which has already received activation from the irregularly inflected prime *fell*, thereby producing processing benefits, leading to a priming effect that cannot be obtain with pseudo-irregular prime-target pairs such as *tell-TALL*.

3.4 Evidence for Position Specific Coding of Suffixes in Morphological Processing

There is emerging evidence suggesting that morpheme encoding is position specific. In other words, non-words containing morphemes in illegal positions (for example, suffixes treated as prefixes, e.g., *fulgas*) should not cause any more interference effects than their respective orthographic controls (e.g., *filgas*). A recent study (Crepaldi, Rastle, & Davis, 2010) has argued for position specific coding of suffixes based on a series of experiments manipulating morpheme position. Specifically, in Experiment 1, Crepaldi et al. (2010) demonstrated that in a lexical decision task, participants needed longer to reject legal non-word combinations of morphologically complex words (e.g., *gasful*) compared to non-morphological orthographic controls (e.g., *gasfil*). However, when the suffixes were prefixed (e.g., *fulgas*), participants did not need longer to reject these scrambled non-words compared to their respective orthographic controls (e.g., *filgas*). These results suggests that when morphemes appear in positions that they are not normally encountered in (e.g., suffixes in a prefix position), they may not be recognised by the visual word processing system. In further experiments Crepaldi et al. (2010) tested the robustness of this theory by introducing additional orthographic fillers (e.g., *hyena*, Experiment 2) to control for the unusual orthographic appearance of scrambled target words (e.g., *oryflip*). In Experiment 3, existing suffixed words were transposed (e.g., *nesskind*) and compared to orthographic controls (e.g., *nusskind*). Both experiments confirmed the findings of Experiment 1, demonstrating that suffixes appear to be processed in a position-specific manner only. Specifically, words containing suffixes in positions usually occupied by prefixes are no more difficult to reject as non-words than their respective orthographic controls. This, however, is not the case for legally suffixed non-words, which produced a reliable interference effect compared to non-morphological non-words. These findings suggest that the visual system codes for suffixes, and perhaps for other morphemic units such as prefixes, in a position specific manner. Possible reasons as to why the visual system benefits from position invariant coding, for example aiding real-time processing speed of morphologically complex words, are yet to be explored.

3.5 Summary

A growing number of studies lend support to the notion that in early visual word processing, morphologically complex words are rapidly decomposed into their constituent stems and affixes. This process occurs within the first 50 or so milliseconds following word recognition and appears to apply to any word that has an apparent legal morphological structure. However, the extent to which semantic factors aid this process is still heavily debated within the literature, with some (e.g., Longtin & Meunier, 2005; McCormick et al., 2008; Rastle & Davis, 2008; Rastle et al., 2004) arguing for a negligible role of semantics in the early stages of word processing, and others (e.g., Diependaele et al., 2011; Feldman et al., 2009) arguing for a contributing role of semantics even in the very early stages of visual word recognition. This debate will be further addressed in the experimental chapters of this thesis. The commencing chapter (Chapter 4) will introduce morphology in the second language this thesis focuses on: German. This will be followed by an overview of models of bilingual word recognition as well experimental evidence relating to morphological processing in bilingual speakers (Chapter 5).

Chapter 4

Word Formation and Morphology in German

4.1 Introduction

This chapter describes word formation processes in German, thereby introducing the second language forming an important component of this thesis. The German language is well known for its ability to produce new, and often very long, words by joining two or more free standing morphemes, a process called compounding. Some new word formations may result in words so long that they are mostly referred to by their acronyms (e.g., *Bundesausbildungsförderungsgesetz (Federal Training Support Act),* commonly referred to as *BAföG*). However, although many new German words are formed by joining nouns, the focus here will be primarily on affixation processes. As already demonstrated in Chapter 1, morphology is the basis of word formation processes, and this chapter provides a brief overview of how inflection and derivation operate in the German language. As the most important definitions and issues associated with morphology (i.e., what is morphology, stem/root/base, productivity, etc.) were already addressed in Chapter 1, this will not be repeated here. In addition, the definitions provided for English in Chapter 1 also apply to the German language, and thus a repetition thereof would be redundant. This chapter therefore follows a similar structure to Chapter 1, with inflection being discussed first, followed by on overview of derivational processes.

4.2 Inflection

4.2.1 Verb Inflection

In German, a verb can express five so-called finite verb forms. These are: person (1st person, 2nd person, 3rd person), number (singular, plural), tense (Present, Preterite, Perfect, Plurperfect, Future, Future perfect), voice (active, passive), and mood (indicative, subjunctive, imperative) (Helbig & Buscha, 2001).

For example, the verb *singen* (sing) can be inflected in the following way:

(1) (ich) sing**e** (1st person, singular, present tense, active, indicative)
(2) (du) sing**st** (2nd person, singular, present tense, active, indicative)
(3) (er/sie/es) sing**t** (3rd person, singular, present tense, active, indicative)
(4) (wir) sing**en** (1st person, plural, present tense, active, indicative)
(5) (ihr) sing**t** (2nd person, plural, present tense, active, indicative)
(6) (sie) sing**en** (3rd person, plural, present tense, active, indicative)

In English, person and number need to be deducted from the syntactic context, with the exception of the 3rd person singular (e.g., *sing**s***). This is also the case for German, although here the person and number of the 1st and 2nd person singular can be identified in isolation. As demonstrated in the above example, the 3rd person singular and 2nd person plural (3 and 5), as well as the 1st and 3rd person plural (4 and 6) are identical. Thus, the syntactic context in which the verb is embedded becomes more important. In German, in addition to the personal pronoun (e.g., ich, du etc.), the person and number of the verb are specified by means of the verb ending (as denoted above in bold). However, the number of a verb is specified in conjunction with either the noun or adjective, depending on the context in which the verb occurs (Helbig & Buscha, 2001).

4.2.2 Weak and Strong Verbs

As in English, German verbs can also be categorised into weak and strong verbs, also known as regular and irregular verbs, respectively. This bears particular relevance to the formation of the past tense and past participle. To form the past tense, regular verbs attach the suffix –**te** to the verb ending (e.g., *lob**te***; praised). To form the past participle, regular verbs attach the prefix **ge-** and suffix **–t** (e.g., ***ge**lob**t***; praised) (Buck, 1999).

Irregular or strong verbs on the other hand form the past tense by changing the vowel of the stem (e.g., *h**e**lfen* (present) – *h**a**lf* (past); help - helped). This change of the stem vowel is a common morphological process in German inflection (see below), and may also be accompanied by consonant changes (e.g., *ste**h**en* – *sta**nd***, stand – stood; *ge**h**en* – *gi**ng***, go –went) (Öhlschläger, 2008). Regular verbs do not tend to change the stem vowel, but can be inflected in the following way: *h**a**ndeln (deal) – h**a**ndelte (dealt) – geh**a**ndelt (dealt).* Irregular verbs, on the other hand also change their stem vowel in the preterite (past tense), as well as the past participle: *f**i**nden (find) – f**a**nd (found) – gef**u**nden (found)* (Helbig & Buscha, 2001. p. 30).

In order to form the past participle, irregular verbs attach the prefix **ge-** and the suffix **–en** (e.g., *helfen* – ***ge**holf**en*****,** help-helped) (Buck, 1999). However, as Öhlschläger (2008) points out, the prefix *ge-* used in inflectional processes (see above, *geholfen*) is not technically a prefix, but a circumfix, as it is always used in conjunction with the suffixes *–en*, or *–t*. Prefixes as such do not occur in German inflection, but are a common occurrence in derivational word formation processes.

There is a further difference between regular and irregular German verbs relating to the formation of the preterite. In order to form the preterite in singular regular verbs, all persons require the addition of a suffix. However, for irregular verbs, only the 2nd person singular requires the addition of a suffix. This is demonstrated in the following examples for the regular verb *fragen* (ask) and the irregular verb *laufen* (walk) (Helbig & Buscha, 2001; pg. 31):

Regular: ich frag-**t-e** (1st person) – du frag-**te-st** (2nd person) – er frag-**te** (3rd person)
Irregular: ich lief (1st person) – du lief-**st** (2nd person) – er lief (3rd person).

The approximately 200 irregular German verbs can be classed into eight main categories and several subcategories, depending on their respective stem vowel. A comprehensive overview of all exceptions can be found in Helbig and Buscha (2001). For the purpose of illustration, four examples are given below (Helbig & Buscha, 2001, pg. 32-34):

1. A voiceless consonant follows the stem vowel (ei-i-i), e.g., gl**ei**ten – gl**i**tt – gegl**i**tten (slide)
2. The consonants nn or mm follow the stem vowel (i-a-o), e.g., gew**i**nnen – gew**a**nn – gew**o**nnen (win)

3. A voiceless s follows the stem vowel (e-a-e), e.g., **e**ssen – **a**ß – geg**e**ssen (eat)
4. The consonants l or m follow the stem vowel (e-a-o), e.g., st**e**hlen – st**a**hl – gest**o**hlen (steal).

It is important to note that in addition to the eight categories and subcategories, there are numerous exceptions in German conjugation, with irregular preterites or past participles. As the purpose of this chapter is provide an overview of the most important aspects of German morphology, this aspect of conjugation will not be explored further.

4.2.3 Conjugation of Verbs

Although affixation is used extensively to conjugate verbs in German, it is important to note that German verb inflection also makes use of auxiliary verbs. The standard German grammar reference, the Duden (Eisenberg, Gelhaus, Henne, Sitta, & Wellman, 1998) lists over 40 sets of 'Konjugationsmuster' (conjugation models, p. 208). A few examples for illustration purposes are given below for the 1st person (ich – I) singular and the verb *liebe* (love):

Ich liebe (I love)

Ich liebte (I loved)

Ich werde lieben (I will love)

Ich würde lieben (I would love)

Ich habe geliebt (I have loved)

Ich hatte geliebt (I loved)

Ich hätte geliebt (I would have loved)

Ich werde geliebt haben (I will have loved)

Ich werde geliebt (I am loved)

Ich würde geliebt haben (I would have loved)

Ich wurde geliebt (I was loved)

Ich würde geliebt (I would be loved)

Ich werde geliebt haben (I will have loved)

Ich bin geliebt worden (I have been loved)

Ich werde geliebt werden (I will be loved) etc.

As outlined by Fox (1990), most of these examples consist of more than one word (e.g., *werde lieben* as opposed to *lieben*), and can be summarised as consisting of the following structures (pg. 105):

> AUXILIARY VERB + TENSE AFFIX - MAIN VERB + PAST PARTICIPLE AFFIX (e.g., habe geliebt; werde geliebt)
>
> AUXILIARY VERB + TENSE AFFIX - MAIN VERB + INFINITIVE AFFIX (e.g., werde lieben)
>
> AUXILIARY VERB + TENSE AFFIX - MAIN VERB + PAST PARTICIPLE AFFIX - AUXILIARY VERB + PAST PARTICIPLE AFFIX – AUXILIARY VERB + INFINITIVE AFFIX (e.g., wird geliebt worden sein).

Fox (1990) regards such forms of inflection requiring auxiliary verbs as being part of morphology. However, he notes that they need to be treated as individual words that undergo specification changes. For example, the auxiliary verb *haben* (have) undergoes similar stem-vowel and consonant changes as described above for verbs, e.g., *haben – hast – hat – hatte – hätte*. However, Fox (1990) points out that despite these individual specification changes, such changes occur in synchrony and therefore establish a reoccurring regularity in these forms. Öhlschläger (2008) on the other hand makes a clear distinction between synthetic inflection and analytic inflection. Synthetic inflection refers to direct changes to the word, e.g., *laufen* (walk) – *lief* (walked) – *gelaufen* (walked). Analytic inflection, on the other hand, refers to those inflectional processes requiring one or more auxiliary verbs, e.g., *ist geliebt worden* (has been loved). Öhlschläger (2008) argues that because contemporary linguistic practice only regards morphological processes as occurring within a single word, only synthetic inflection can be regarded as truly morphological. Analytic inflection (i.e., the inflection of auxiliary verbs in conjunction with main verbs) is a result of syntactic changes and constructions, and should therefore not be regarded as inflection within a morphological context. However, he also points out that these analytic inflections are sometimes regarded as belonging to inflections in general, in which case they are called periphrases. Periphrases are conjunctions for which there is no alternative morphological expression in German; in other words, no other form of inflection of the main verb can express the particular tense of the analytic inflection. One example is *ist geliebt worden* (was loved), which is both passive voice and perfect, and cannot be expressed any other way (Öhlschläger, 2008). It therefore appears that periphrases can potentially be classed as inflections; however, this only applies if the periphrase is regarded as a lexeme paradigm that expresses morphosyntactic properties for which there is no other available form (Öhlschläger, 2008). For the purpose of simplicity, the remainder of the discussion on inflection will focus only on syntactic inflectional processes.

In summary, although German verb inflection does contain some complexities, it is important to note that there are a number of suffixes that strongly point toward verb inflection. These suffixes include:

Singular

-**e**	(1st person)	**-t**(e)	(1st & 3rd person, past)
-**st**	(2nd person)	-**te**(st)	(2nd person, past)
-**t**	(3rd person)	**-ge -t / -ge –en** (past participle)	

Plural

-**en**	(1st person)	-**t**(en)	(1st & 3rd person, past)
-**t**	(2nd person)	-**te**(t)	(2nd person, past)
-**en**	(3rd person)	**-ge -t**	(past participle)

4.2.4 Noun Inflection

In order to understand German noun inflection, or declination, the declination of the definite article, akin to the English ‘the’, has to be described. The definite article, in conjunction with the noun, demonstrates whether a noun is masculine, feminine, or neuter. In addition, it also denotes, again in conjunction with the noun, the case in which the noun appears. German cases are the nominative, accusative, genitive, and the dative. The definite article can therefore be declinated as follows (adapted from Buck, 1999; pg. 32):

	Singular			Plural
	Masc	*Fem*	*Neut*	*All genders*
Nominative	**der**	**die**	**das**	**die**
Accusative	**den**	**die**	**das**	**die**
Genitive	**des**	**der**	**des**	**der**
Dative	**dem**	**der**	**dem**	**den**

When the German noun is declinated, the definite article and the noun ending change, depending on case, gender, and number. For example, the singular German noun is declinated the in the following way (Buck, 1999, pg. 35-36; Helbig & Buscha, 2001, pg. 211-222):

(Mensch = human, Lehrer = teacher, Blume = flower, Haus = house)

	Masculine	*Feminine*	*Neuter*
Nom	der Mensch/Lehrer	die Blume	das Haus
Acc	den Mensche**n**/Lehrer	die Blume	das Haus
Dat	dem Mensche**n**/Lehrer	der Blume	dem Haus
Gen	des Mensche**n**/Lehrer**s**	der Blume	des Haus**es**

As can be seen in the above example, there are two ways in which the masculine singular noun can be declinated, whereas the feminine singular noun does not change at all. The neuter singular noun only adopts the –s ending in the genitive case.

The formation of plural nouns in German is identical for masculine, feminine and neuter nouns, and only differs for the dative, in which case the noun adopts the ending –s (Buck, 1999). Thus, the plural is declinated as follows:

Nom	die Väter (fathers)
Acc	die Väter
Dat	den Väter**n**
Gen	der Väter

Despite the apparent simplicity of plural declination, there are in fact five different types of plural declination, and several exceptions with regards to foreign words used in German. For the purpose of this overview, however, the above example should suffice. A more detailed listing of all exceptions and categories can be found in Helbig and Buscha (2001). Stated succinctly, it can be said that the most important noun suffixes in German are: *–(e)n*, denoting masculine, singular nouns for the Accusative, Genitive, and Dative, as well as the plural of the Dative for all genders; and *–(e)s*, denoting the Genitive for masculine and neuter singular nouns.

4.2.5 Adjective Inflection

The German adjective which describes a noun is declinated according to the gender, number, and case of the noun. In addition, this process depends on whether the adjective forms the beginning of a sentence and as such is not preceded by other words (e.g., in exclamations such as *Schöne Ferien!* Have a lovely holiday!), and conversely on whether it is preceded by a personal pronoun, or other pronouns, such as *kein(e)* (no/none) (Eisenberg et al., 1998). As a comprehensive overview of all variants of the declinated adjective would encompass not less than 140 different forms, the example below is restricted to adjectives not preceded by any articles, and shows only the singular form: (langer Saal = long hall; helle Sonne = bright sun; spannendes Buch = exciting book)

	Masculine	*Feminine*	*Neuter*
Nom	langer Saal	helle Sonne	spannendes Buch
Acc	lange**n** Saal	helle Sonne	spannendes Buch
Dat	lange**m** Saal	helle**r** Sonne	spannende**m** Buch
Gen	lange**n** Saal(es)	helle**r** Sonne	spannende**n** Buch

As in English, German adjectives also form a comparative. Mostly, this is formed through synthetic inflection, and in exceptions also with the help of analytic inflection (Helbig & Buscha, 2001). Most adjectives take on the endings *–er* to form the comparative and the ending *–est* or *–st* to form the superlative. In addition, there is a fourth form in German, called elative. The elative form is also referred to as the absolute superlative, and takes on the ending *–ste* (Helbig & Buscha, 2001). The comparative for the adjective *kalt* (cold) is formed as follows:

absolute	*comparatives*	*superlative*	*elative*
kalt	kält**er**	kält**est**	kälte**ste**

As can be seen in the example above, in all three comparative forms the stem vowel *a* changes into the umlaut *ä*. However, this vowel change only applies to a small number of 18 monosyllabic words (Helbig & Buscha, 2001). All other words containing a stem vowel do not adopt umlauts when forming the comparative or superlative. Just as in English, German also has irregular adjectives for which the comparative is irregular. For example, for the word *gut* (good) the comparative is formed as *gut – besser – am besten*, whereby the superlative is formed with a preposition.

Taken together, the most important suffixes for adjective inflection *are –e, –(e)m, -(e)n, -(e)r*, and *–(e)s*, whereas the suffixes used to form the adjective comparative are *–er, -est,* and *–ste*.

4.3 Derivation

Word formation in German does not only take place by means of joining two or more free standing morphemes (compounding), but also through affixation. In fact, some estimates suggest that less than 5% of German nouns are monomorphemic, and those words that are regarded as monomorphemic in modern German are actually compounds in terms of their etymology (West, 1994). For example, the word *Blume* (flower) is a derivation from *blühen* (to flower) in combination with the suffix *–me*, which is no longer in use in modern German (Fox, 1990). In addition, monomorphemic words in German are either borrowed from other languages such as Latin (e.g., *Duzend*; dozen), or belong to early acquired core vocabulary (e.g., *Mond*, *Hund*; moon, dog) (West, 1994).

4.3.1 Types of Derivatives

As in English, derivatives in German can also be formed for several word classes, both through the use of prefixes as well as suffixes. The most common derivations are listed below.

4.3.2 Prefix Derivations

4.3.2.1 Verb Derivatives

Prefixes such as *ver-, be-, ent-, er-*, *miß-* and *zer-* can be attached before verbs, adjectives or nouns to form new verbs (Eisenberg et al., 1998). All of these prefixes can change the meaning of a word in several ways. For example, *ver-* can express the termination of certain processes (e.g., *ver+blühen* – to fade/wither (flower)) when attached to verbs, or express a process of change when attached to nouns (e.g., *ver+Sumpf+en* – become swamp-like) or adjectives (e.g., *ver+arm+em* – become poor) (Eisenberg et al., 1998). The prefixes *miss-, fehl-, de-, in-,* and *ge-* on the other hand have invariable meanings, and are only used for a small number of verbs. They are classed as little (*miss-, fehl-, de-, in-)* or not at all productive (*ge-*). In addition, German has a number of very productive free standing prefixes, including *ab-, aus-, ein-,* and *auf-* (Eisenberg et al., 1998); these productive prefixes can also occur as freestanding morphemes in their own right. For a list of the most common German prefixes see Appendix 2.

4.3.3 Suffix Derivations

Noun Derivatives

In German, noun suffixation often results not only in the formation of new words, but also in a change of the gender of the noun. For example the suffixes *–schaft, -heit* or *–ung* will always result in feminine nouns, even when attached to masculine or neuter monomorphemic nouns. For example, if the masculine noun *der Mann* (man) takes on the suffix *–schaft*, it forms the feminine noun *die Mannschaft* (team) (Fox, 1990; p. 170). Therefore, the gender of noun-to-noun derivatives is specified by the type of suffix the noun takes on (Fox, 1990).

There are several suffixes that are attached to German nouns in order to form noun derivatives. The following examples of German noun suffixes are based on Buck (1999; p. 112-113):

> *-chen* (e.g., *Kind – Kindchen; child – little child*). The suffix *–chen* always results in a diminutive in German, and thus the resulting derivative is always neuter.
>
> *-ei/-erei* (e.g., *Mätzger – Mätzgerei; butcher – butcher shop*). Attached to nouns, apart from denoting a trade, this suffix may also describe perpetual activities, e.g., *die Frage – die Fragerei* (*question – continuous questioning*). Attached to verbs, it denotes activities or trades (e.g., *backen – Bäckerei; bake – bakery/baking*).
>
> *-er* (e.g.*, England – Engländer; England – English person*). When attached to nouns, this suffix often denotes nationality. However, *-er* is most commonly

attached to verbs, and results in trades or tools, e.g., *schweissen – der Schweisser (welding – welder)*.

-heit (e.g., *weise – Weisheit; wise – wisdom*). Often attached to adjectives, these noun derivatives denote attributes or traits.

Other common noun suffixes include *–in, -keit, -lein, -ling, -schaft, -tum,* and *–ung*. In addition to native suffixes, German makes use of a range of foreign suffixes to form new words, including *–ant* (e.g., *Demonstrant; demonstrator*), *-ie* (e.g., *Psychologie*; *psychology*), and *–or* (e.g., *Diktator; dictator*) (West, 1994. pg. 35). A comprehensive overview of German noun suffixes can be found in Appendix 2.

4.3.4 Adjective Derivatives

In order to form adjectives from verbs, three suffixes are used in particular, which are *–bar, -lich*, and *–abel* (Eisenberg et al., 1998). For example, *-bar*, when added to verbs, denotes positive or negative (with the help of the prefix *un-*) attributes of nouns (e.g., *essbare Frucht*; edible fruit), akin to the English suffix *–able* (e.g., *passierbar* – passable; *ungenießbar* – uneatable) (Eisenberg et al., 1998). The suffix *–lich* on the other hand often denotes certain qualities (e.g., *sportlich* – sporty), and is often used for colours (e.g., *gelblich* – yellowish) (Buck, 1999).

Adjective derivations can also be formed from nouns, and there is a variety of German suffixes that can be taken on by nouns. For example, *-esk, -al/ell, -ar/är*, and *-ös/os* are suffixes that can only be attached to nouns (e.g., *formell – formal*); in addition, there is a variety of suffixes that can be attached to both nouns and verbs in order to form adjective derivatives (Eisenberg et al., 1998). A few examples of these suffixes are listed below (for an overview, see Appendix 2):

-ig	(e.g., öhlig oily)
-lisch	(e.g., fraglisch – questionable)
-mäßig	(e.g., zweckmäßig – purposeful)

4.3.5 Adverb Derivatives

The most common suffixes attached to adjectives or nouns in order to form adverbs is *–s* (Eisenberg et al., 1998), forming adverbs such as *abends* (in the evenings). Other adverbial suffixes include *–dings, -links, -wärst,- -weise, -er*, as well as *–fach, -mal*, and *–tens* (Eisenberg et al., 1998).

4.4 Summary

This chapter has provided a brief overview of the most important and common aspects of German morphology. Where applicable, comparisons with the English language were drawn, in order to demonstrate similarities and differences. As outlined above, that existence of cases as well as several tenses cause German morphology to be, in part, more complex than English morphology, and can cause problems for the learners of German as a foreign language or late bilinguals. The next chapter will introduce this bilingual aspect of language processing and describe models of bilingualism, as well as explore empirical evidence for morphological processing in bilinguals.

Chapter 5

Visual Word Processing in Bilinguals

5.1 Introduction

The ability to speak more than one language is a world-wide phenomenon and being bilingual is both common and necessary in many countries around the world. In fact, some people argue that true monolingual speakers are becoming a rare phenomenon (Cook, 2003). In some countries (e.g., Uganda, Israel, Pakistan) there is one official language whilst numerous regional and foreign languages are spoken throughout the country. Other countries, such as Belgium, or Canada, are known as bilingual countries, and both official languages tend to be known across the country, even in economically weaker groups.

Initially, children who grow up bilingually have difficulties separating the two languages in speech (Bialystok, 2007). However, late bilinguals who have already firmly established their first language (L1) rarely have difficulties separating their L1 from their L2. This chapter reviews some explanations of how bilingual speakers are able to separate their L1 from their L2 and how they are able to correctly identify language membership of visually presented words. In addition, this chapter provides an introduction to the behavioural evidence related to morphological processing in bilingual speakers.

5.2 Models of Bilingual Visual Word Processing

5.2.1 The Revised Hierarchical Model of Bilingual Word Processing

The Revised Hierarchical Model (RHM) of bilingual word processing (Kroll & Stewart, 1994) (Figure 9) has taken a dominant stand for over a decade in bilingual word recognition research.

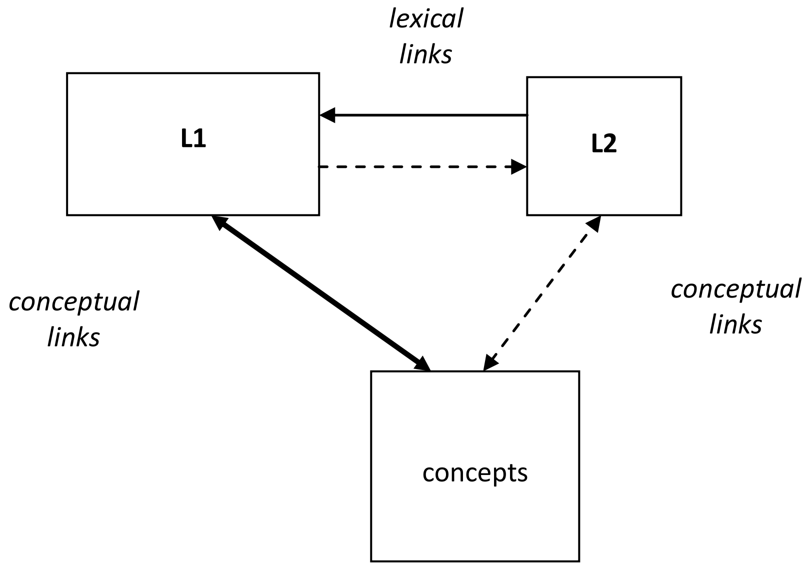

Figure 9. The Revised Hierarchical Model of bilingual word processing. Redrawn from Kroll and Stewart (1994). L1 = native language, L2 = second language.

In principle, the model was based on three experiments exploring category interference effects during picture naming and word translation (Kroll & Stewart, 1994). In Experiment 1, the researchers demonstrated that when native English speakers were asked to name lists of words and lists of pictures, pictures organised semantically (as opposed to randomly) within lists produced an interference effect, slowing down naming by up to 36ms. In contrast, semantic blocking of words was not found to have an effect on word naming. It was argued that the semantic blocking of pictures caused one and the same semantic category to be continuously accessed. This raises activation levels at both the conceptual and the lexical level, leading to higher competition among closely related items, thereby slowing down picture naming. In Experiment 2 (Kroll & Stewart, 1994), pictures and words alternated within one and the same list. Lists were organised either semantically or randomly. This methodology reduced the level of conceptual activation, but maintained lexical activation levels. Results with native English speakers indicated that if pictures and words are blocked according to their semantic category, the previously obtained category interference effect is no longer observed. These results indicate that the category interference effects obtained in Experiment 1 stem from increased activation at the concept level, and not merely increased activation at the lexical level. In Experiment 3, the category interference effect was tested in proficient bilingual speakers of Dutch and English. Participants were presented with English and Dutch lists containing words (e.g., dress, shirt, lion etc.) which were organised semantically or randomly. Participants were required to name the translation of the presented word. In general, translations from L1 into L2 took longer than translations from L2 into L1. The category interference effect was only found when participants translated from their L1 into their L2, whereas L2 to L1 translations were unaffected by semantic blocking.

Kroll and Stewart (1994) proposed the Revised Hierarchical Model of bilingual word processing to account for these behavioural results. As can be seen in Figure 9, the authors first assumed that the L2 lexicon is smaller than the L1 lexicon, reflecting the finding that in particular late bilinguals know many more words in their L1 compared to their L2. In addition, lexical and conceptual links differ in strength depending on the level of proficiency of L2. Generally within the model it is assumed that there are stronger lexical links from L2 to L1 than from L1 to L2, which demonstrate the acquired translation links between a native and a second language. The stronger link from L2 to L1 is argued to be caused by the way a second language is initially acquired, implying that translations are primarily learned from L2 to L1 and not L1 to L2. Over time, as proficiency increases, lexical links also form from L1 to L2, although these links will always remain weaker. Kroll and Stewart (1994) further argued that during L2 acquisition, L2 does not directly access the conceptual system storing the meaning of words. Rather, L2 access to concepts is mediated by the strong links between L2 words and L1 words and between L1 words and concepts. Only over time L2 forms direct, albeit weaker conceptual links.

Kroll and Stewart (1994) argued that the results of their Experiment 3 demonstrated that the category interference effect was only present when participants translated from L1 to L2. This was interpreted as the result of the active concept mediation between L1 towards L2. The effect of semantic blocking was not found for translations from L2 to L1 because of the strong lexical links formed between L2 and L1 during L2 acquisition. The authors argued that these results were a demonstration of the asymmetries between L1 and L2 for bilinguals who had a firmly established native language before learning their second language, requiring conceptual and lexical mediation between the two.

5.2.2 Further Experimental Evidence in Support of the Revised Hierarchical Model

Initially, the main ideas of the Revised Hierarchical Model, namely the separation of the L1 and L2 lexicons, the selective access to each of those lexicons, as well as the distinction between lexical and conceptual components of language processing, appeared to be in line with evidence from the literature (Brysbaert & Duyck, 2010). For example, Dufour and Kroll (1995) found that bilingual fluency affects the way words can be categorised in relation to their meaning. The authors demonstrated that there was no significant difference in proficient English-French bilinguals' ability to categorise French and English words, irrespective of whether category lists contained words from only one language (L1 or L2; within category), or words from both L1 and L2 (between category). This suggests that with increasing L2 fluency, there are direct mappings between the L2 lexicon and the conceptual system, so that conceptual mediation via L1 is no longer required. Less proficient bilinguals on the other hand performed slowest in the between language category, even slower than in the within L2 category. This suggests that there may be some form of direct but weak access from L2 to the conceptual system, but that this access is still partially mediated by the L1 lexical system. However, as proficiency increases, the links between L2 and concepts become stronger, and no more concept mediation from L1 is required. Other evidence also supports the notion of asymmetry between L1 and L2. Keatly, Spinks, and de Gelder (1994) studied Chinese-English and French-Dutch bilinguals who were tested on a cross-language priming paradigm. The results demonstrated significant priming effects from L1 to L2 but not from L2 to L1. This pattern was independent of differences in the languages' scripts. Keatly et al. (1994) further demonstrated that although French-Dutch translation equivalents produced some bi-directional priming, a pronounced asymmetry remained, with more priming from L1 to L2 compared to L2 to L1. The authors interpreted these results as in line with separate language stores, although they argued that the asymmetry between L1 and L2 reflects the stronger interconnectivity of L1 to a range of different memory systems, rather than just to the conceptual system as proposed by the Revised Hierarchical Model.

5.2.3 Evidence Against the Revised Hierarchical Model

Despite the initial support for separate language systems in bilingual visual word recognition (for a review, see Kroll and de Groot, 1997), a growing number of studies challenge the fundamental assumptions of the Revised Hierarchical Model. In a recent review article, Brysbaert and Duyck (2010) discuss evidence that poses strong objections to the notion of separate lexicons, selective lexical access, and lexical connections between languages. With respect to the assumption of separated lexicons for L1 and L2, recent neuropsychological studies suggest that similar cortical areas are involved in both L1 and L2 processing. For example, Illes et al. (1999) demonstrated that the left inferior frontal gyrus is active for semantic processing in both languages of late bilingual speakers of Spanish and English. This suggests that even when L2 acquisition has taken place after the age of 10, proficient bilingual speakers make use of the same cortical areas in both their L1 and L2. The argument in favour of proficiency rather than age of acquisition in relation to cortical activation was also put forward by Perani et al. (1998), who found no significant differences in L1 and L2 cortical activity for both early and late highly proficient English-Italian and Catalan-Spanish bilinguals during a comprehension task. Only bilinguals with low L2 proficiency exhibited significantly different patterns of cortical activation between L1 and L2. Further support for the notion that bilinguals make use of similar cortical areas in both their L1 and L2 was presented in a meta-analysis conducted by Indefrey (2006). Several studies reviewed in the meta-analysis showed that areas usually associated with L1 processing, such as the left inferior frontal cortex, are also active in L2 processing. This indicates that at least in some word identifications tasks, L2 speakers need to involve brain regions that would normally be active during native language processing.

A growing number of behavioural studies also challenge the Revised Hierarchical Model's assumption of selective lexical access in bilingual word processing. One influential eye-tracking study demonstrating simultaneous L1 and L2 activation was conducted by Spivey and Marian (1999). In the experiment, late Russian-English bilinguals were presented with a range of familiar items (e.g., stamp, matches, marker, etc.). In one of the conditions, the participants were instructed in Russian to perform certain actions, such as to pick up one item and place it underneath another. Despite the experiment being performed in a monolingual Russian context, eye-tracking demonstrated that when participants were asked to select a certain target such as *marku* (stamp), their eyes also briefly fixated on an interlingual distractor item *flomaster* whose English translation *marker* shares initial phoneme overlap with the Russian target *marku*, indicating an interference effect between L1 and L2. More recent evidence has also made a case for cross-over effects between L1 and L2 in bilinguals. For example, in an eye-tracking experiment, Van Assche, Duyck, Hartsuiker, and Diependaele (2009) investigated native language sentence reading in Dutch-English bilinguals. Inserting Dutch-English cognates (e.g., sport, student, winter) into Dutch sentences (e.g., Kris had nooit gedacht dat de STORM/STRAF zo zwaar zou zijn. / Kris never thought that the STORM/PUNISHMENT would be so severe.), the researchers showed that compared to Dutch control words, initial fixations and gaze durations on cognates were significantly shorter. The authors argued that the findings support the notion of non-selective language access in bilinguals, implying that even during a purely monolingual task, knowledge of a second language has a profound impact on native language processing.

5.3 The Bilingual Interactive Activation Model

In response to the challenges posed to Kroll and Stewart's (1994) Revised Hierarchical Model, Dijkstra, Van Heuven, and Grainger (1998) and Van Heuven, Dijkstra, and Grainger (1998) proposed a computational model of bilingual word processing, the Bilingual Interactive Activation (BIA) model (see Figure 10). The BIA is a bilingual extension of the original IA model (McClelland & Rumelhart, 1981) described in Chapter 2. It is an extension in so far as it includes a complete Dutch lexicon in addition to the English lexicon of the original IA, as well as a language level incorporating both the English and the Dutch lexicon; this language level is connected to both lexica contained within the word level (Van Heuven et al., 1998). In principle, the BIA’s feature and letter levels operate similarly to the IA model. In the BIA, features activated by visual input activate matching letters at the letter level shared by both languages, and inhibit all letters that do not match visual input (see also Figure 10). This language non-selective approach continues at the word level where words from both languages inhibit each other, and only activated words send feedback to the letter level. However, activated Dutch words only feed activation forward to the Dutch language node at the language level, and in turn, activated English words only activate the English language node at the language level. As presented in Figure 10, language selective inhibition only takes place at the language level. Here, the activated English language node inhibits Dutch words at the word level, and conversely, the activated Dutch language node inhibits all English words at the word level.

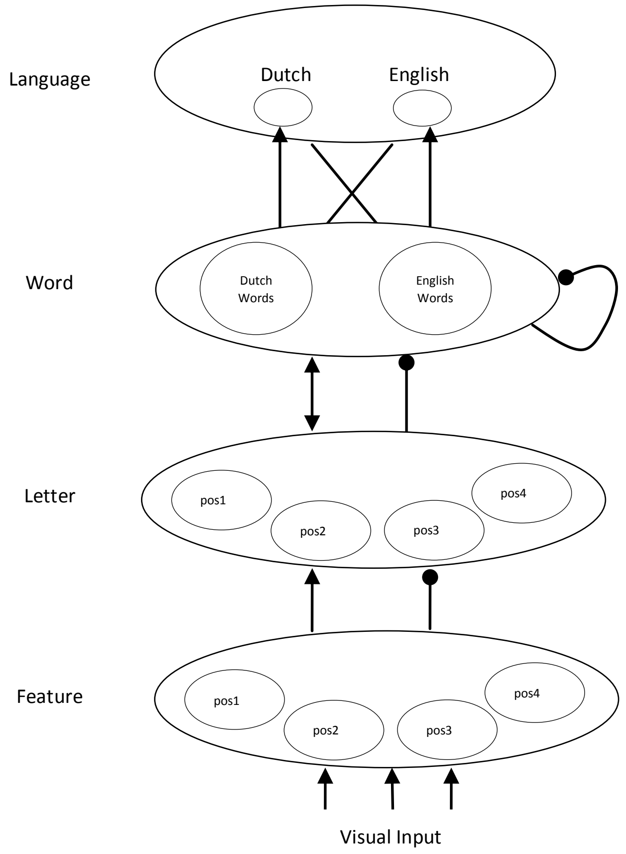

Figure 10. The Bilingual Interactive Activation (BIA) model. Redrawn from Van Heuven et al. (1998).

Overall, simulations conducted with the BIA model mirrored results obtained in four behavioural experiments conducted with Dutch (L1) – English (L2) bilinguals. In experiments one to four Van Heuven et al. (1998) demonstrated that:

a) in progressive demasking, target word recognition in one language is significantly inhibited by a large target neighbourhood (N) in the participant's other known language (e.g., English target words with a large Dutch N are responded to more slowly compared to English targets with a small Dutch N)
b) in progressive demasking, when both languages (Dutch and English) are presented randomly within one and the same experimental block, the inhibitory influence of the other language's N on target word recognition becomes even stronger
c) in lexical decision, with both languages (Dutch and English) being presented randomly within one and the same experimental block, the inhibitory influence of N is strongest from L1 to L2, i.e., English (L2) target words are identified more slowly when they have many Dutch (L1) neighbours; the reverse effect is less strong
d) in lexical decision, Dutch N significantly affects Dutch native speakers' performance in English by slowing down target recognition, whereas monolingual English speakers' performance is unaffected by a large Dutch N.

Although the BIA was able to simulate the behavioural results obtained in the above experiments, in particular the inhibitory effects of the other known language's large N (Van Heuven et al., 1998), the model was only built to simulate orthographic representations and was subsequently revised and updated by

Dijkstra and Van Heuven (2002) (see Figure 11). The revised BIA+ model attempts to account for phonological and semantic information and provides an indication of how bilinguals are affected by non-linguistic task components, although this model has not been computationally implemented.

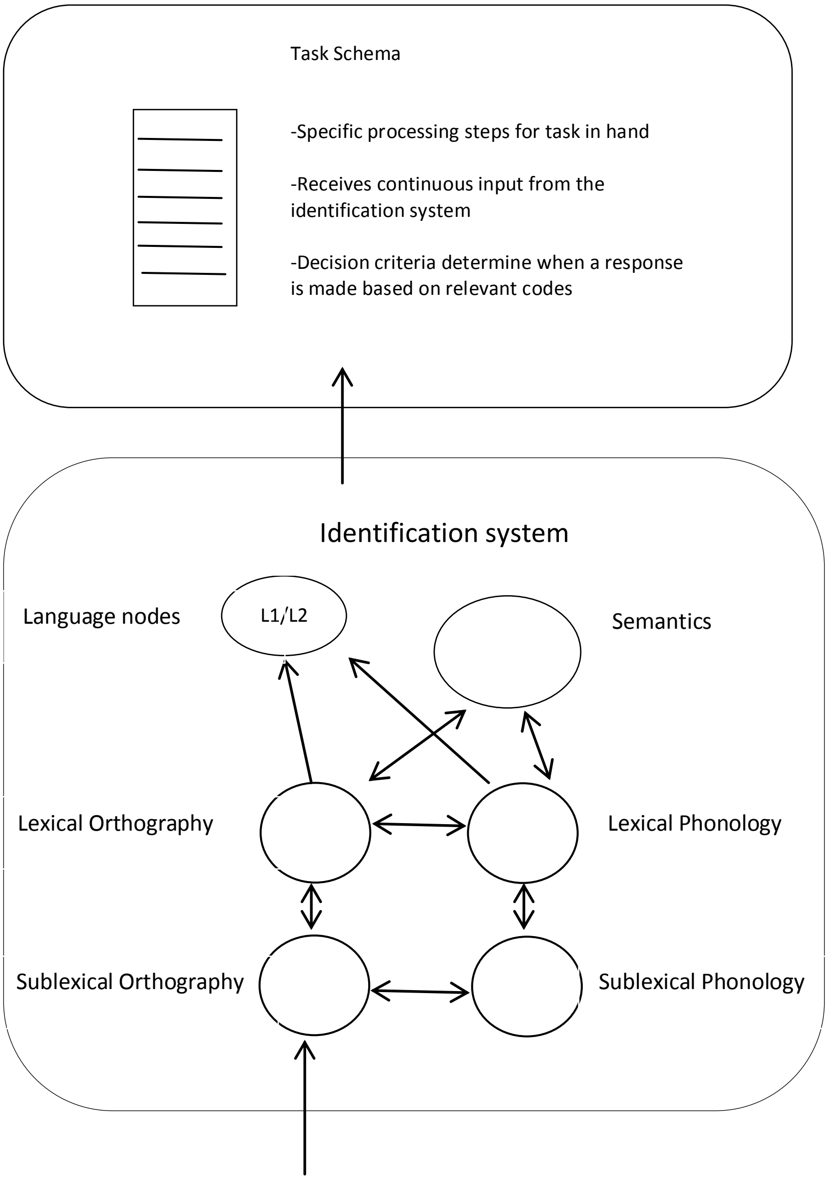

Figure 11. The BIA+ Model. Redrawn from Dijkstra and Van Heuven (2002).

As can be seen in Figure 11, the BIA+ model (Dijkstra & Van Heuven, 2002) includes many of the elements of the BIA. As in the BIA, orthographic representations matching the input string are activated in both languages. However, in the BIA+, matching representation of phonology as well as semantics will also receive activation in both L1 and L2. Most of the evidence in support of cross-lingual phonological and semantic activation comes from research into interlingual homograph and cognate effects (e.g., Dijkstra, Grainger, & Van Heuven, 1999; Lemhöfer & Dijkstra, 2004; Van Hell & Dijkstra, 2002a; see also the study by Van Assche et al., 2009, discussed above). For example, it has been demonstrated with Dutch-English bilinguals that when participants have to respond to targets in both their L1 and L2 within one and the same experiment, interlingual cognates sharing orthographic, semantic and phonological representations across the two languages (e.g., *film, sport*) activate shared semantic representations that facilitate target recognition; on the other hand, interlingual homographs (e.g., *cow* – *kou* (cold in Dutch)) sharing similarities in sound and spelling but not in semantics do not produce cross-language facilitation effects (Lemhöfer & Dijkstra, 2004). These findings can be explained within the BIA+ model. In essence, it is assumed that, compared to orthographic representations, phonological and semantic codes are activated with some delay in L2 rather than being activated simultaneously in both languages. L1 codes will generally be activated faster compared to L2 codes, causing cross-linguistic effects to be more pronounced from L1 to L2 compared to L2 to L1 (Dijkstra & Van Heuven, 2002). If experimental tasks are constructed in such a way that decisions have to be made in both L1 and L2 (e.g., Lemhöfer & Dijkstra, 2004), both the L1 and L2 codes are activated. However, the faster L1 code will ultimately influence decision making, causing no benefit for interlingual homographs. On the other hand, interlingual cognates that benefit from simultaneous orthographic activation prior to shared phonological and semantic activation, show clear cross-linguistic facilitation effects (Dijkstra & Van Heuven, 2002; Lemhöfer & Dijkstra, 2004). When tasks are performed in L1 only, there are clear interlingual facilitatory effects for words sharing orthographic and semantic overlap between L1 and L2, but inhibitory effects for words sharing phonological overlap between L1 and L2 (Lemhöfer & Dijkstra, 2004). This shows that the BIA+ is able to account for task dependent performances, as well as the apparent language non-selective access taking place in bilingual visual word processing.

With respect to language representation, in comparison to the BIA, language nodes in the BIA+ are limited in their functionality. The language nodes' function lies within the domain of language representation. This means that they aid the decision making process of which language a visually presented word belongs to, rather than acting as filters between languages (Dijkstra & Van Heuven, 2002). In particular, the language nodes no longer inhibit the word nodes belonging to the other language.

In sum, although only the orthographic recognition system of the BIA+, which it also shares with the BIA model, has been implemented thus far, this computational model promises to be a stepping stone for models of bilingual word processing. However, challenges remain, such as the modelling of multilingual word processing and proficiency effects (Brysbaert & Duyck, 2010). In addition, it would be interesting to account for auditory bilingual word processing, for example, how the bilingual word identification system is able to tag language membership during speech processing. A further issue relates to morphological processing. Similar to monolingual computational models, neither the BIA nor the BIA+ currently address how bilingual speakers are able to process morphologically complex words in their L2, and how this in turn affects L1 processing. Despite a growing number of behavioural studies exploring morphological processing in bilingual speakers, no clear picture has yet emerged as to whether L2 morphological processing follows that of L1, or whether there are clear differences in how bilinguals process morphologically complex words in their respective languages. The following section provides a short review of recent psycholinguistic experiments exploring this issue.

5.4 Morphological Processing in Bilinguals

As already outlined in Chapters 2 and 3, there is debate as to whether all apparent morphologically complex words are rapidly decomposed in early visual word processing as proposed by Rastle, Davis, and New (2004) and Rastle and Davis (2008), or whether semantic components play a significant role in the decomposition process (e.g., Feldman, O'Connor, & Moscoso del Prado Martin, 2009). With respect to morphological processing in bilinguals, a similar debate exists. However, here the issue is not only related to the rapid decomposition of apparent morphological items in L1, but whether morphologically complex words in L2 are processed akin to L1, and to what extent age of acquisition, language similarity in terms of morphological richness, and L2 proficiency play a role in this process.

In a series of masked-priming experiment, Silva and Clahsen (2008) studied how Chinese, Japanese, and German native speakers process regular past-tense forms in their second language, English (e.g., *folded* – *FOLD*) (Experiment 1 and 2). The experiment included three conditions, an identity condition (e.g., *boil* – *BOIL*), a morphologically related condition (e.g., *boil* – *BOILED*) and an unrelated condition (e.g., *jump- BOIL*). At an SOA of 60ms, the control group of English native speakers showed priming in both the morphologically related and identical condition, but needed longer to respond to unrelated items. On the other hand, Chinese and German L1 speakers tested in English only showed priming in the identity condition, but not in the test and unrelated condition (see Table 4). At an SOA of 30ms, Japanese native speakers also showed priming for the L2 identity condition but no priming for both the morphologically related and the unrelated condition, whereas English native speakers' performance mirrored that of the 60ms SOA. Silva and Clahsen (2008) argued that the absence of priming in the morphological test condition in English L2 speakers indicates that non-native speakers of English do not make use of the same decomposition processes as L1 speakers when they encounter morphologically complex words. Rather, English L2 learners, irrespective of the similarity of script and morphological richness between their native language and English[5], tend to store morphologically complex words as whole items, and not as separate stems and affixes.

Table 4. Mean Reaction Times in milliseconds for Silva and Clahsen (2008), Experiments 1 and 2.

English L1			Chinese L1			German L1		
Identity	*Test*	*Unrelated*	*Identity*	*Test*	*Unrelated*	*Identity*	*Test*	*Unrelated*
451	463	518	646	757	730	553	618	612

However, in other experiments (Experiments 3 and 4), Silva and Clahsen (2008) found that English L2 speakers do show partial priming patterns with de-adjectival suffixes such as *-ness* and *–ity* and attributed these results to the derivational, as opposed to the inflected (Experiment 1 and 2), nature of the items.

In contrast, Lehtonen, Niska, Wande, Niemi, and Laine (2006) found bilingual speakers to process inflected words similarly to native speakers (see Table 5). In a lexical decision task, the authors tested native Swedish speakers and early Finnish-Swedish bilinguals on Swedish monomorphemic and inflected words of low, medium and high frequency. Swedish native speakers processed low frequency inflected words more slowly than low frequency monomorphemic words, but showed no difference in processing speed between monomorphemic and inflected

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[5] German and English both use Arabic script and are similar in terms of their morphological richness, although German can be argued to be morphologically richer than English (compare Chapter 1 and 4). Japanese and English and Chinese and English are more dissimilar, both in use of script and morphological richness, with Chinese not making use of affix type morphemes (Silva & Clahsen, 2008).

medium and high frequency words. Bilingual speakers followed a similar trend to that of native speakers. Bilingual speakers also showed longer processing times for low frequency inflected items.

Table 5. Mean Reaction Times in milliseconds for Lehtonen et al. (2006).

Frequency	Item	Swedish L1	Finnish-Swedish Bilinguals
Low	Monomorphemic	657	704
	Inflected	738	802
Medium	Monomorphemic	617	638
	Inflected	625	677
High	Monomorphemic	597	626
	Inflected	605	633

Compared to monomorphemic items, bilinguals' reaction times were slower for inflected items across all frequency ranges, although this difference was only significant for the low and medium frequency category. However, the fact that bilinguals follow a trend similar to that of monolinguals in processing inflected words may be language dependent and related to the morphological richness of the language. For example, Lehtonen and Laine (2003) (see Table 6) studied Finnish native speakers and early Finnish-Swedish bilinguals, employing a methodology akin to Lehtonen et al. (2006). The target language of the study was Finnish, a morphologically richer language than both Swedish and English. Results indicated that Finnish native speakers process low frequency inflected items slower than both medium and high frequency inflected items. In comparison to monomorphemic items, inflected items were processes slower across all frequencies. Interestingly, bilinguals' reaction times were slower for low frequency items overall, irrespective of the morphological status of the items. In general, reaction times for inflected items were slower than for monomorphemic items although these two main factors did not interact for any of the frequency categories.

Table 6. Mean Reaction Times in milliseconds for Lehtonen and Laine (2003)

Category	Item	Finnish L1	Finnish-Swedish Bilinguals
Low	Monomorphemic	639	791
	Inflected	742	900
Medium	Monomorphemic	567	673
	Inflected	587	724
High	Monomorphemic	567	641
	Inflected	580	714

The authors argue that these findings suggest that bilingual speakers appear to employ one and the same processing approach to low and high frequency items. The difference between monolingual and bilingual speakers was attributed to the fact that native speakers encounter high frequency items more often than non-native speakers; therefore, native speakers store high frequency items as wholes to improve quick access, and employ a decomposition process to low frequency items. Bilingual speakers on the other hand encounter all inflected words less frequently, regardless of their frequency, and therefore need to apply a decomposition process to all inflected items.

There is some evidence to suggest that the similarity in script and morphological richness of a speaker’s L1 influences morphological processing in L2. Basnight-Brown, Chen, Hua, Kostić, and Feldman (2007) employed cross-modal priming in three experiments, investigating how native English speakers, and Serbian (L1) – English (L2) and Chinese (L1) –English (L2) bilinguals process English verbs with irregular stem changes (e.g., *bought-BUY*), as well as irregular nested (e.g., *drawn-DRAW*) and regular past tense forms varying in the overlap of their semantic richness or resonance (e.g., *guided-GUIDE* – low resonance; *pushed-PUSH* – high resonance). The findings (see Table 7) showed that for monolingual English speakers, reaction times were faster for regular high resonance compared to low resonance items. They also responded faster to irregular nested as compared to irregular stem change items, although both categories facilitated target recognition. An interesting trend emerged for bilinguals speakers. Participants with Serbian, a more regular and inflected language than English, as their first language showed a pattern of results similar to that of English native speakers for regular verbs, although for irregular verbs, only irregular nested items produced facilitation. Chinese native speakers, however, only followed the monolingual results for regular verbs, with more facilitation for high resonance verbs. Results for Chinese L1 speakers showed no facilitation for irregular verbs. The authors argue that these results are best explained in light of the similarities between the Serbian and English language, both in the use of an alphabetic script as well as the reliance on form similarity and morphological structure within the language, both of which are not present in Chinese.

Table 7. Facilitation in milliseconds for English as target language, adapted from Basnight-Brown et al. (2007).

	English L1	*Serbian L1*	*Chinese L1*
Irregular Nested	64*	85*	12
Irregular Stem change	38*	11	11
Regular low resonance	65*	80*	38*
Regular high resonance	54*	86*	26*

*p<0.05

Research by Portin et al. (2008) has also suggested that the structure of L1 influences morphological processing in L2. Late Hungarian (L1) –Swedish (L2) and Chinese (L1) –Swedish (L2) bilinguals took part in a lexical decision experiment studying reaction times to monomorphemic and inflected Swedish words of low, medium and high frequency. Hungarian L1 speakers were slower to react to inflected compared to monomorphemic items, but were only significantly slower for inflected words of low and medium frequency. In contrast, Chinese L1 speakers' reaction times were slower overall for low frequency items, but there was no difference in overall RTs to inflected versus monomorphemic items. The authors suggest that Hungarian L1 speakers applied morphological decomposition strategies to process low and medium frequency words, but stored high frequency words as full-form items, aiding rapid access during processing. Thus it appears that Hungarian speakers apply decomposition strategies in their L2, whereas Chinese L1 speakers do not appear to process monomorphemic and morphologically complex words differently (Portin et al., 2008).

Although a recent review (Clahsen, Felser, Neubauer, Sato, & Silva, 2010) claims that bilinguals rely more on full-form processing in their L2 and rarely apply L1 strategies to process morphologically complex words, there is evidence to suggest that bilingual speakers apply L1 strategies in L2. In a masked priming experiment, Diependaele, Duñabeitia, Morris, and Keuleers (2011) (see Table 8) studied the processing of English morphologically complex transparent, opaque, as well as form control items (see Rastle et al. (2004) and Chapter 3). Comparing native English speakers with proficient Spanish (L1) – English (L2) and Dutch (L1) – English (L2) bilinguals, the authors demonstrated that all three groups of participants followed a similar trend, with most facilitation for transparent items, medium facilitation for opaque items, and comparatively less facilitation for form items, although form priming effects are larger in the English L2 speakers than in the English L1 speakers. These findings indicate that in early visual word processing, bilinguals make use of similar strategies in both L1 and L2.

Table 8. Mean Reaction Times in milliseconds for Diependaele et al. (2011). Target Language English.

Category	**Item**	**English L1**	**Spanish L1**	**Dutch L1**
Transparent	Related prime	592	654	699
	Control prime	628	689	734
	Priming Effect	*36*	*35*	*35*
Opaque	Related prime	612	683	709
	Control prime	627	708	735
	Priming Effect	*15*	*25*	*26*
Form	Related prime	636	703	744
	Control prime	637	717	758
	Priming Effect	*1*	*14*	*14*

In summary, this chapter provided a brief overview of models of bilingual visual word processing, describing how the dominant view of separate language systems has been challenged by models of non-selective language processing. Further, this chapter demonstrated how current research into bilingual morphological processing has provided contradictory findings, with some arguing for distinct processes for L1 and L2, and others favouring integrated accounts, arguing that bilingual speakers make use of the same processing strategies for morphological processing in both their L1 and L2 (see also Table 9, pg. 134).

To establish whether L2 processing does indeed follow L1 processing, the experiments presented in this work sought to investigate morphological processing in German (L1) – English (L2) and English (L1) – German (L2) bilinguals. Specifically, Experiments 1, 2, 3, and 4 (Chapters 6 and 7) tested how bilingual speakers process transparent, opaque, and form control items in both their L1 and their L2. This allowed for direct observations of native language and second language processing on similar items across the two languages. Experiment 5 (Chapter 8) tested whether the results obtained in Experiments 1-4 could be explained by the effects of prime frequencies on morphological processing. This experiment was carried out with native English speakers. Experiment 6 (Chapter 9) was conducted to study prime frequency effects on L2 morphological processing in German-English bilingual speakers. Finally, Experiment 7 was carried out to act as a monolingual English control to Experiment 1, examining whether the bilingual status of participants in Experiment 1 affected the magnitude of morphological processing in L1.

Table 9. Summary of Research into Morphological Processing in Bilingual Speakers.

Study	**Languages**	**Morphology Studied and Methodology**	**Results**
Basnight-Brown et al. (2007)	English (L1) Serbian (L1) – English (L2) Chinese (L1) – English (L2)	Irregular and regular past tense forms Test language: English Cross modal priming task – lexical decision	*Regular verbs:* bilinguals similar in facilitation to native speakers *Irregular verbs:* Serbian L1 similar to native English only on nested stem change; Chinese L1 no facilitation
Diependaele et al. (2011)	English (L1) Spanish (L1) – English (L2) Dutch (L1) – English (L2)	Form, opaque and transparent morphological items Test language: English Masked priming task (SOA: 50ms) - lexical decision	Native and bilinguals speakers follow same trend: most facilitation for transparent items medium facilitation for opaque items no facilitation for form items in native speakers, but medium facilitation for form items in bilinguals
Lehtonen and Laine (2003)	Finnish (L1) early Finnish-Swedish bilinguals (both languages acquired before school)	Low, medium, and high frequency monomorphemic and inflected Finnish items Test language: Finnish Lexical decision task	*Finnish L1 speakers* – slower RT for inflected items, particularly low frequency *Bilingual speakers* – no difference in RT between monomorphemic and inflected items though slower overall RTs for low frequency items
Lehtonen et al. (2006)	Swedish (L1) early Finnish-Swedish bilinguals (both languages acquired before school)	Low, medium, and high frequency monomorphemic and inflected Swedish items Test language: Swedish Lexical decision task	Native and bilinguals speakers follow similar trend – slower RTs for low frequency inflected items. Bilinguals also slower for medium inflected items.
Portin et al. (2008)	Hungarian (L1) – Swedish (L2) Chinese (L1) – Swedish (L2)	Low, medium, and high frequency monomorphemic and inflected Swedish items Test language: Swedish Lexical decision task	*Hungarian L1*: slower RTs for inflected low and medium frequency items *Chinese L1*: no difference in RT between monomorphemic and inflected items though slower overall RTs for low frequency items
Silva and Clahsen (2008)	English (L1) German (L1) – English (L2) Chinese (L1) – English (L2) Japanese (L1) – English (L2)	Experiment 1: Regular past-tense forms SOA 60ms Experiment 2: Regular past-tense forms SOA 30ms Experiment 3 and 4: derivational suffixes –ity and –ness, SOA 60ms Test language: English Masked priming task – lexical decision	Experiments 1,3 & 4: English L1 priming for inflected and derived forms; Chinese L1 and German L1 no priming for inflected items, partial priming for derived items Experiment 2: Japanese L1 no priming for inflected items

Chapter 6

Morphological Processing of Bilingual Speakers in English

6.1 Introduction

It has been argued that in early visual word processing, morphologically complex words are rapidly decomposed into their constituent morphemes (Rastle, Davis, & New, 2004), by means of segmenting the affix from its root (e.g., *walk+er*) (see also Chapters 2 and 3). Several studies have supported the notion that this process takes place whenever a word contains an apparent morphological structure. Indeed, apparently complex primes such as *corner* have been shown to aid the processing of the target word *corn* akin to the magnitude of facilitation found for prime-target pairs such as *walker* - *walk* (e.g., Longtin, Segui, & Halle, 2003; Rastle & Davis, 2008; Rastle et al., 2004). In relation to bilingual morphological word processing, however, experimental findings have been more inconsistent. The bilingual morphological literature comprises of evidence supporting a whole-word processing account (e.g., Clahsen, Felser, Neubauer, Sato, & Silva, 2010; Silva & Clahsen, 2008), as well as language dependent affix stripping (e.g., Lehtonen & Laine, 2003; Lehtonen, Niska, Wande, Niemi, & Laine, 2006). Although several claims have been made that bilinguals employ L1 strategies in their L2 (e.g., Diependaele, Duñabeitia, Morris, & Keuleers, 2011; Lehtonen et al., 2006; Portin et al., 2008), experiments rarely test bilinguals in both their respective languages. Often, a separate group of native speakers is selected to function as a control group instead. Because of this, it is difficult to draw firm conclusions as to whether bilingual speakers indeed employ similar strategies in both their L1 and L2. In relation to morphological processing, thus far only a few studies into bilingual word processing (e.g., Diependaele et al., 2011) have made use of the prime-target manipulations employed, for example, by Rastle et al. (2004). This makes it difficult to draw comparisons between native and bilingual morphological processing with respect to the 'form-then-meaning' account. Further, to the author's knowledge, no studies to date have applied these particular morphological and semantic prime-target manipulations to both the bilinguals' L1 and L2 for one and the same participant group. Experiments 1 and 2 (this chapter), and 3 and 4 (Chapter 7), were therefore designed to explore whether bilingual speakers of two similar languages, English and German, make use of comparable strategies to process morphologically complex words in each of their respective languages. Experiments 1 and 2 tested whether bilingual English L1 and L2 speakers demonstrate the 'form-then-meaning' account of morphological processing observed for English native speakers by Rastle et al. (2004).

6.2 Experiment 1: English (L1) – German (L2) Bilinguals

6.2.1 Method

6.2.1.1 Stimuli

Ninety suitable prime-target pairs (see Appendix 3 for a complete list of stimuli) were selected from the CELEX English database (Baayen, Piepenbrock, & van Rijn, 1995). The experiment consisted of three categories containing 30 target words each: a transparent, opaque and form category (see below). For each target word in each category, a related prime was selected, manipulating the semantic and morphological relationship between prime and target (see below). For each individual related prime, an additional control prime was selected, which bore no semantic relationship with the related prime and contained no letter in the same position. Thus, each of the three conditions contained two types of primes, a related prime, and a control prime (see Table 10, p. 138 for examples).

Form condition: Prime-target pairs that were neither semantically nor morphologically related were selected. For primes to be included in this condition, the non-overlapping endings with targets had to form non-morphological letter strings. This resulted in non-overlapping letter strings such as *oozle, ica, b,* or *llor.* The resulting prime-target couplings formed pairs such as *blurb-blur*. Great care was taken that non-overlapping prime endings did not represent legal suffixes in German. This applies for example to English form prime-target pairs such as *colonel – colon*, and *brothel-broth*. The primes here end in the letter string *–el*, which does not present a suffix ending in English, but functions as a very frequent morphological ending in German.

Opaque condition: Prime-target pairs that had no apparent semantic relationship but an apparent morphological relationship were selected. Thus, each prime contained the target as well as a legal suffix ending, but bore no semantic relationship with the target word itself, resulting in prime-target pairs such as *adultery-adult*.

Transparent condition: Prime-target pairs were chosen that were both semantically, orthographically and morphologically related. Thus, each prime contained both the target as well as a legal suffix, and thus presented a derivation or an inflection of the target word, resulting in prime-target pairs such as *guardian – guard*, or *selfish – self.*

Table 10. Examples of prime-target pairs for all conditions of Experiments 1 and 2 (English as L1 and L2).

	Transparent	*Opaque*	*Form*
Related prime -target	employer - EMPLOY	glossary - GLOSS	freeze - FREE
Control prime - target	contrast - EMPLOY	dumpling - GLOSS	polish - FREE

Across conditions, primes and targets were matched closely on frequency, neighbourhood size, letter length and overlap (see Table 11). Suffix frequencies for words in the opaque and transparent condition were compiled by counting the total number of words that contained each suffix in the morphological category of the CELEX (Baayen, Piepenbrock, et al., 1995) database. This frequency count does not account for pseudomorphological endings, such as in the English word *corner*. An independent samples t-test was performed to establish whether suffix frequencies differed significantly between conditions. As shown in Table 11, there was no significant difference in the suffix frequencies between the opaque and transparent condition.

Table 11. Comparison of measures across conditions for Experiment 1 and 2 (English as L1 and L2).

Measure	Form	Opaque	Transparent	ANOVA
Target Frequency*	1.5	1.3	1.4	F(2,87)=1, p>0.05
Raw Target Frequency	*69*	*44*	*44*	
Related Prime Frequency*	0.6	0.9	0.7	F(2,87)=1.78, p>0.05
Raw Related Prime Frequency	*8*	18	8	
Control Prime Frequency*	0.6	0.8	0.7	F(2,87)=1.494, p>0.05
Raw Control Prime Frequency	*7*	24	8	
Target Length	4.8	5	5.1	F(2,87)<1, p>0.05
Related Prime Length	7.4	7.3	7.3	F(2,87)<1, p>0.05
Control Prime Length	7.4	7.3	7.3	F(2,87)<1, p>0.05
Target Neighbourhood	2.2	2.4	1.8	F(2,87)=1.128, p>0.05
Related Prime Neighbourhood	0.6	0.6	0.4	F(2,87)<1, p>0.05
Control Prime Neighbourhood	0.4	0.7	0.5	F(2,87)=1.013, p>0.05
Related Prime-Target Letter Overlap	0.6	0.7	0.7	F(2,87)=1.694, p>0.05
Control Prime-Target Letter Overlap	0.6	0.7	0.7	F(2,87)=1.632, p>0.05
Suffix Frequency	n.a.	831	1094	t(58)=-1.14, p>0.05

** Log per million*

6.2.1.2 Exclusions

As all participants were bilingual speakers of German and English, certain items that could potentially influence reaction times (see Chapter 5 for a discussion on cognates and homophones) were not included. For all conditions, words that were cognates or homophones in German and English (e.g., *bank, pilot, brand, butter*) were excluded as target words. Words that had considerable but no complete orthographic overlap between English and German, and at the same time were semantically related or identical in their meaning (e.g. *music – Musik, infect – Infekt, magic – Magie*) were also excluded as targets, but were used as unrelated primes.

Trials with non-word targets: Ninety filler non-word items were selected for the 'no' response. In order to match the non-word to the word conditions, word prime-target pairs that had originally been selected for inclusion in the word conditions but for various reasons, such as neighbourhood size or meaning relationship with

German, were not included in the final selection process, were manipulated. Targets were changed into non-words by changing one letter in the original target or two letters in targets above a length of six letters. Thirty non-word targets were primed by a word prime with no suffix ending, and 30 non-word targets were primed by a word prime with a suffix ending. A further 30 non-word targets were compiled with the help of WordGen (Duyck, Desmet, Verbeke, & Brysbaert, 2004). These were preceded by unrelated morphologically complex word primes. All non-word targets were matched to word targets on length and neighbourhood size. All primes preceding non-words targets were matched to all other primes in this experiment as described above.

6.2.1.3 Procedure

Using a Latin-square design, targets were divided into two lists, A and B, of equal size. In each list, each word target was presented only once, paired either with the related prime, or the unrelated control prime. Participants saw either list A or list B; thus, participants saw each word target item only once. Non-word trials were identical in both lists and presented to all participants. Each file contained 180 trials. The presentation of stimuli was controlled and randomised by the DMDX software (Forster & Forster, 2003) which also recorded the reaction times. The files were run on a personal computer.

Each trial was preceded by a fixation star remaining in the centre of the screen for 500ms, followed by a blank screen for 200ms. This was followed by a hash mask '###########' presented for 500ms. The hash mask fully masked the commencing prime. The prime was presented immediately following the hash mark. All primes were presented in lower case in the centre of the screen for 42ms. Immediately following the prime, the target was presented in upper case letters in the centre of the screen and remained there until a response was made. If no response was made, after 3000ms the message ‘too slow’ appeared, and the trial was scored as an error, and was followed by the next trial.

Participants were tested in a dimly lit room, one person at a time. For the lexical decision task, participants were seated approximately 50cm away from the computer screen and presented with a button box, containing two buttons labelled ‘yes’ and ‘no’. Participants were instructed that the experiment involved viewing a series of letter strings that would either form a real word, or a letter string that does not exist in the English language. They were instructed that their task was to decide, as quickly and accurately as possible, whether the letter string on screen formed a real English word or not, by pressing either the ‘yes’ or ‘no’ button provided. Participants were not told about the presence of the prime. Instructions on screen prior to commencing the experiment were given in English. Each participant received 10 practice trials prior to the experiment.

6.2.1.4 Participants

Participants were 26 English (L1) – German (L2) bilinguals, who also participated in Experiment 4 (Chapter 7). Participants were recruited on campus, and were both students and members of staff. At the time of the experiment, the majority of participants were studying for the degree course ‘German’. All participants self-assessed English to be their first and dominant language. A bilingual assessment was undertaken prior to their participation in Experiment 4 (see Chapter 11). All participants had normal or corrected-to-normal vision, and had no known diagnosis of a reading disorder. Participants were offered £10 in exchange for their time (in conjunction with Experiment 4).

6.3 Results

Reaction time (RT) data were analysed by means of a 3*2 factorial ANOVA, with RT as dependent variable, and condition (3 levels: form, opaque, transparent) and prime type (related, control) as factors. Condition was treated as within factor in the analysis over participants (F1) and as between factor in the analysis over items (F2). Prime relatedness was treated as a within factor in both the F1 and F2 analysis. List was treated as a between factor in both F1 and F2. Errors made (96 data points) were excluded. Data were cleaned and only RTs between 100ms and 2000ms were included in the analysis, resulting in the removal of 7 (0.31%) out of 2,244 data points. No items were deleted as all received a correct response from more than half the participants. Mean RTs and SDs for Experiment 1 are presented in Table 12.

Table 12. Experiment 1 – English as L1 in English L1-German L2 bilingual speakers. Mean Reaction Time (RT) in milliseconds, Standard Deviation (SD) and Priming Magnitude per Condition.

	Transparent (SD)	*% Error*	*Opaque (SD)*	*% Error*	*Form (SD)*	*% Error*
Related prime	670 *(210)*	1.8	676 *(210)*	3.1	703 *(223)*	5.6
Control prime	705 *(222)*	2.8	696 *(222)*	4.9	723 *(254)*	6.4
Priming effect	*35*	*1*	*20*	*1.8*	*20*	*0.8*

Results showed that there was a significant effect of condition over participants [$F_1(2,48)=6.13$, $p<0.01$; $F_2(2,84)=1.70$, n.s.]. Although post-hoc Bonferroni contrasts demonstrated no significant difference between conditions (all ps>0.05), planned comparisons (significant over participants only) showed that transparent [$t_1(25)=3.50$, $p<0.01$; $t_2(58)=1.46$, n.s] and opaque items [$t_1(250=2.90$, $p<0.05$; $t_2(58)=1.63$, n.s.] were responded to faster than form items. There was a significant effect of prime type [$F_1(1,24)=30.77$, $p<0.001$; $F_2(1,84)=12.850$, $p<0.01$], with related primes being responded to faster than unrelated primes. There was no interaction between condition and prime [$F_1(2,48)<1.14$, n.s.; $F_2(2,84)<1$, n.s.].

Errors

Error analyses for English native bilingual speakers showed a significant difference in the distribution of errors across condition over participants [$F_1(2,48)=61.64$, $p<0.01$; $F_2(2,84)=2.90$, n.s.]. Although post-hoc Bonferonni tests showed no significant difference in the number of errors made between conditions (all ps>0.05), planned comparisons showed that compared to the transparent condition, significantly more errors were made in the form [$t_1(25)=3.59$, $p<0.01$; $t_2(39.326)=2.16$, $p<0.05$] and opaque (significant over participants only) [$t_1(25)=2.18$, $p<0.05$; $t_2(42.232)=1.072$, n.s.] conditions than in the transparent condition. There was no significant effect of prime type [$F_1(1,24)=2.46$, n.s.; $F_2(1,84)=2.52$, n.s.] with respect to the number of errors made. Further, there was no interaction between condition by prime in relation to the distribution of errors [$F_1(2,48)<1$, n.s.; $F_2(2,84)<1$, n.s.].

6.4 Experiment 2 – German (L1) – English (L2) Bilinguals

6.4.1 Methods

The stimuli and procedures were identical to Experiment 1.

6.4.1.1 Participants

Participants were 40 German (L1) – English (L2) bilinguals, who also participated in Experiment 3 (Chapter 7). The majority of participants were recruited on campus and were both students and members of staff. Some participants were also recruited through an online web-forum ‘Deutsche in London’. At the time of the experiment, all participants were either studying at Royal Holloway, University of London, or worked in a professional capacity on or off campus. All participants self-assessed German to be their first and dominant language. On average, all but one participant first acquired English around the age of ten (range 3-14), and felt comfortable speaking English at 16 years of age (range 7-27). Only one participant had acquired English first at the age of 39 and felt comfortable speaking the language aged 45[6]. A bilingual assessment was undertaken for all participants prior to their participation in this experiment (the results are discussed in conjunction with the English (L1) – German (L2) bilinguals in Chapter 11).

All participants had normal or corrected-to-normal vision, and had no known diagnosis of a reading disorder. Participants were offered £10 in exchange for their time (in conjunction with Experiment 3), and if recruited off campus, received a further £10 to compensate for their travel expenses.

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[6] Results were analysed with and without this participant’s data. Results did not differ significantly; thus all analyses were performed including this participant’s data.

6.4.2 Results

Results were analysed as described in Experiment 1. Four items drew errors from more than half the participants and were not included in the analysis[7]. Data were cleaned and errors removed (5.2%). Only RTs between 100ms and 2000ms were included in the analysis. No further data points needed to be removed. Mean RTs and standard deviations are presented in Table 13.

Table 13. Experiment 2 – English as L2 in German L1-English L2 bilinguals. Mean Reaction Time (RT) in milliseconds, Standard Deviation (SD) and Priming Magnitude per Condition.

	Transparent (SD)	*% Error*	*Opaque (SD)*	*% Error*	*Form (SD)*	*% Error*
Related prime	719 (204)	4	763 (264)	8.5	734 (227)	7.7
Control prime	752 (227)	7.6	780 (251)	11.8	767 (240)	10.5
Priming effect	*33*	*3.6*	*17*	*3.3*	*33*	*2.8*

Analyses showed a significant main effect of condition over participants [$F_1(2,76)=12.55$, $p<0.001$; $F_2(2,80)=1.32$, n.s.]. Although post-hoc Bonferroni corrected tests showed no difference between conditions (all ps>0.05), planned comparisons (significant over participants only) showed that participants responded faster to transparent than both form [$t_1(39)=2.27$, $p<0.05$; $t_2(55)=0.76$, n.s.] and opaque items [$t_1(39)=4.43$, $p<0.001$; $t_2(55)=1.62$, n.s.], and also faster to form compared to opaque items [$t_1(39)=-3.17$, $p<0.01$; $t_2(55)=-0.90$, n.s.]. Opaque items were responded to slowest overall. Results further showed a main effect of prime type [$F_1(1,38)=12.54$, $p<0.01$; $F_2(1,80)=9.82$, $p<0.01$], with targets preceded by related primes being responded to faster than targets preceded by unrelated

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[7] Deleted items were: form: quartz-QUART, wrench-WREN; opaque: feudal-FEUD; transparent: frothy-FROTH

primes. There was no significant interaction between the main factors [$F_1(2,76)<1$, n.s.; $F_2(2,80)<1$, n.s.].

Errors

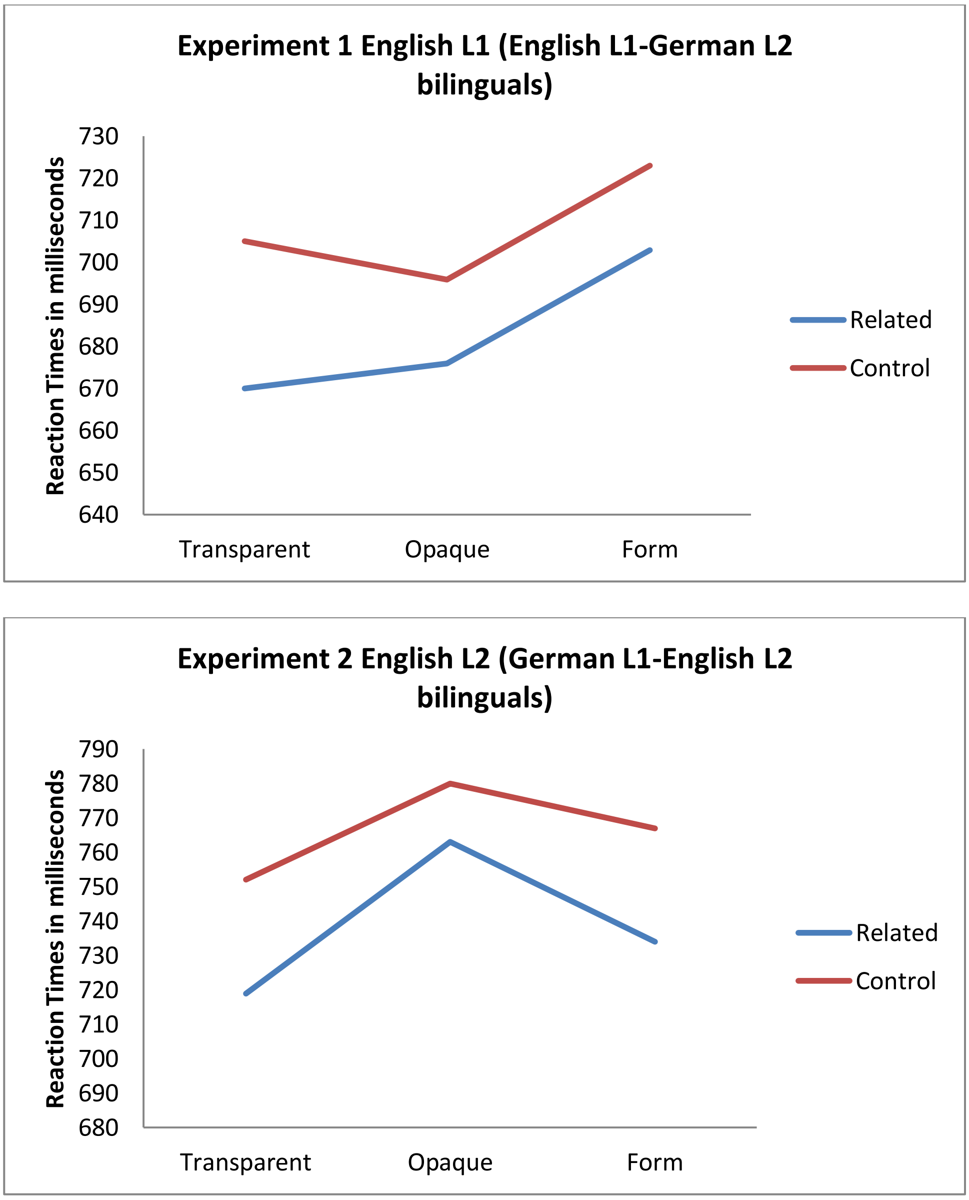
Error analyses for German speakers of English followed a similar trend to the reaction time analysis for correct responses, and showed that there was a significant difference between conditions in the number of errors made to targets over participants only [$F_1(2,76)=5.80$, $p<0.01$; $F_2(2,80)=1.01$, n.s.]. Bonferroni corrected post-hoc tests showed no difference between conditions (all ps>0.05). However, planned comparisons (significant over participants only) showed that compared to the transparent condition, more errors were made both in the opaque [$t_1(39)=3.20$, $p<0.01$; $t_2(56)=1.41$, n.s.] and in the form condition [$t_1(39)=2.70$, $p<0.05$; $t_2(55)=1.06$, n.s.]. Also, there was a significant difference in the number of errors made with respect to prime type [$F_1(1,38)=11.94$, $p<0.01$; $F_2(1,80)=8.15$, $p<0.01$]. More errors were made to targets preceded by control primes. The interaction between condition and prime type was not significant [$F_1(2,76)<1$, n.s.; $F_2(2,80)<1$, n.s.).

6.5 Comparison Experiment 1 and 2

The cleaned data files of Experiments 1 and 2 were combined. Items that had previously been deleted in one but not the other file were removed for the combined file. Results were analysed by means of a mixed model analysis (for a comparison between Experiment 1 and 2, see also Figure 12). Mixed models have several advantages over traditional F1 and F2 analyses. For example, mixed models allow for the combining of F1 and F2 into one single analysis. By doing so, participant and item variation can be treated as a 'crossed random effect' within one single analysis (Baayen, Davidson, & Bates, 2008; p. 2). This increases statistical power, particularly for the item analysis, whilst holding the Type 1 error constant (Baayen et al., 2008). Mixed models are also ideal for psycholinguistic data as they are robust to missing data effects, a common problem in traditional ANOVA analyses (Baayen et al., 2008; Jaeger, 2008), and are better suited for data where the number of observations varies across cells (Janssen, in press).

The combined analysis for Experiments 1 and 2 included the fixed effects of condition (form, opaque, transparent), prime type (related, control), and language (English L1, English L2), as well as their interactions. Further, random intercepts for participants, items, and lists were included. Mixed effect analyses were carried out in SPSS as suggested by Brysbaert (2007). Analyses were performed with the DJMIXED add on package for SPSS (version 19), which is an extension specifically written for conducting mixed models in SPSS, as described by Janssen (in press).

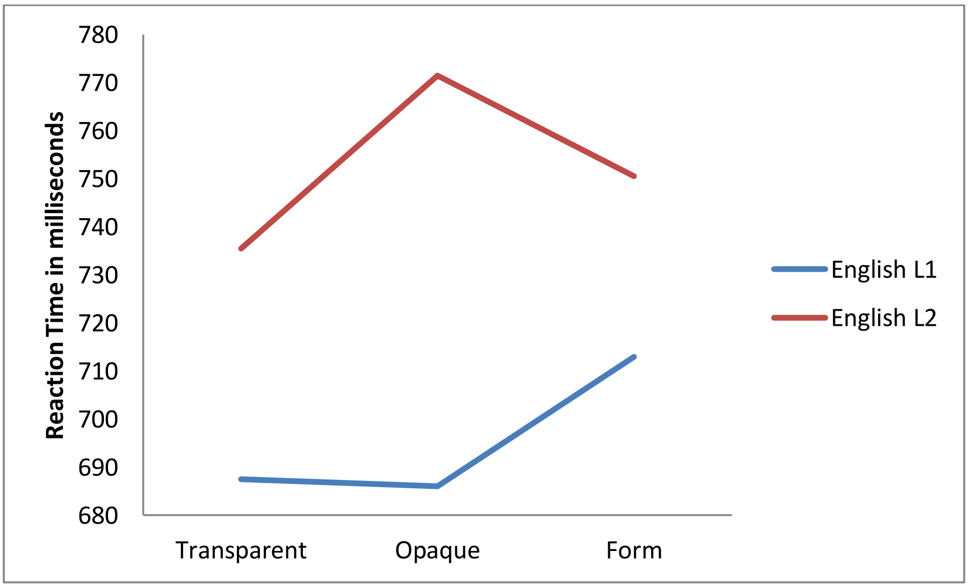
Figure 12. Reaction times in ms for English as L1 and L2 for related and unrelated items, collapsed over form, opaque and transparent conditions.



6.5.1 Results

Mixed effects analyses with DJMIXED revealed that there was no overall significant effect of condition [F(2,84)<1, n.s.]. The main effect of prime type was significant [F(1,5120)=35.21, p<0.0001]. Targets preceded by related primes were responded to faster (M=717) than targets preceded by unrelated primes (M=746). The interaction between prime and condition was not significant [F(2,5120)<1, n.s.]. Analyses further showed a significant main effect of language [F(1,66)=4.54, p<0.05], with English L1 bilinguals making faster overall decisions (M=695) than English L2 bilinguals (M=761). The interaction between language and condition was significant [F(2,5121)=7.68, p<0.001]. As can be seen in Figure 13, overall, English L1 speakers were fastest in the opaque condition, whereas English L2 speakers were slowest in the opaque condition.

Figure 13. Mean reaction times for English L1 and English L2 bilingual speakers collapsed across all conditions.



Errors

Mixed effects analyses showed no significant overall difference in the number of errors made for condition [F(2,87)<1, n.s.]. More errors were made for primes preceded by control than related primes [F(1,5492)=7.40, p<0.01]. The interaction between prime and condition was not significant [F(2,5491)<1, n.s.]. Analyses showed a significant difference in the number of errors made for language

[F(1,66)=13.73, p<0.001], with more overall errors made by English L2 speakers compared to English L1 speakers. No other effects were significant.

6.6 DISCUSSION

The purpose of Experiment 1 and 2 was to investigate whether the findings of Rastle et al. (2004), demonstrating similar facilitation effects for opaque and transparent items but little facilitation for form items, could be replicated in native English bilinguals and extended to English L2 speakers.

For bilingual English L1 speakers, the findings of Experiment 1 did not confirm the trend demonstrated by Rastle et al. (2004). Specifically, a consistent priming effect across all three conditions was found, irrespective of the morphological or semantic relationships between items. In particular, there was a similar magnitude of priming between transparent and form items (35ms versus 20ms, respectively), and equal priming between the opaque and form condition (20ms). Overall, targets preceded by related primes were responded to faster. However, this effect did not differ between conditions. These results are in contrast to several studies that have shown clear differences in the priming magnitude between transparent, opaque and form items in English native speakers (e.g., Diependaele et al., 2011, Experiment 1; Feldman, O'Connor, & Moscoso del Prado Martin, 2009; Longtin et al., 2003; McCormick, Rastle, & Davis, 2008; Rastle et al., 2004). However, a recent study by Duñabeitia, Kinoshita, Carreiras, and Norris (2011; Experiment 2) with Spanish native speakers also demonstrated equal facilitation for transparent (45ms), opaque (46ms), and form (39ms) type prime-target pairs in a masked priming experiment. However, it should be noted that the methodology employed by Duñabeitia et al. (2011) was different to that of Experiment 1. Specifically, the authors employed a same-different task, whereby a reference stimulus either identical or different to the target is presented initially for 1000ms. This is followed by a masked prime, which is then followed by the target, to which a same or different response (in relation to the reference stimulus) has to be made. It is therefore unclear whether the methodology employed by Duñabeitia et al. (2011) contributed to the pattern of results obtained by the authors.

For German native speakers, Experiment 2 also demonstrated robust priming facilitation across all three conditions, with equal facilitation for form and transparent items (33m), and somewhat less priming in the opaque condition (17ms), although this difference was not significant. Interestingly, Diependaele et al. (2011, Experiments 2 and 3) also found increased form priming in English L2 speakers (14ms), although this was less than that observed for transparent (35ms) and opaque (25 and 26ms, respectively) items. The results of Experiment 2 are also contrasted by those of Silva and Clahsen (2008), who showed that adult learners of English show no evidence of priming in their L2. However, the stimuli of Experiments 1 and 2 also differ those of Silva and Clahsen (2008) with respect to the range of suffixes used (Experiments 1 and 2 used a wide range of suffixes, whereas Silva and Clahsen (2008) used only *–ity* and *–ness*), and the semantic and morphological manipulations of the prime-target relationship.

In comparing bilingual English L1 and L2 speakers, it becomes apparent that the two groups performed similarly on the lexical decision task. Both L1 and L2 speakers responded faster to transparent items, though only numerically so, and to targets preceded by related primes. Overall, English L1 bilinguals were faster in their decision latencies across all conditions. The only noteworthy difference between English L1 and L2 speakers was that in Experiment 2, German native speakers were numerically faster in their reaction to transparent compared to opaque items, whereas English L1 speakers in Experiment 1 showed comparable RTs for transparent and opaque items. However, although both L1 and L2 speakers were faster for transparent compared to form items, the contribution of the morphological status of the prime in this respect is unclear. Overall, however, it can be said that the performance of English L1 and L2 speakers followed a similar trend.

The most surprising finding of Experiments 1 and 2, however, was the large amount of form priming obtained for both English L1 and L2 speakers, a trend not commonly reported in the morphological priming literature. However, recently published research with a larger number of observations (25) and participants (66 for Experiment 2, and 65 for Experiment 3) found medium form priming (14ms) for Spanish-English and Dutch-English bilingual speakers (Diependaele et al., 2011). In addition, a recent study by Duñabeitia et al. (2011; Experiment 2) found comparable priming magnitudes across the form, opaque, and transparent condition (39ms, 46ms, and 45ms, respectively) for 34 native Spanish participants in an experiment containing 21 observations per condition. One possible contributing factor to the large form priming obtained in Experiments 1 and 2 relates to the frequency of the primes relative to their targets (see Table 11, pg. 139). Compared to the opaque and transparent condition, the relative frequency of the form targets in relation to form primes was higher. It has been demonstrated that lower frequency primes facilitate the recognition of their higher frequency targets (Segui & Grainger, 1990). Thus, the possible contribution of the relative prime-target frequency to the priming magnitude obtained with form items has to be explored further (see Chapter 8).

Experiments 3 and 4 (Chapter 7) were conducted in order to ascertain whether the results of Experiments 1 and 2 in this work can also be observed in the participants' respective L1 or L2, German, or whether here participants show morphological priming patterns similar to those demonstrated by Rastle et al. (2004).

Chapter 7

Morphological Processing of Bilingual Speakers in German

7.1 Introduction

The experiments presented in Chapter 6 explored morphological processing in English (L1) – German (L2) as well as German (L1) – English (L2) speakers in the English language. It was demonstrated that English L1 and L2 speakers process morphologically complex (transparent and opaque) and form control items to a similar degree, with significant priming magnitudes across all three experimental conditions. The experiments also revealed a large amount of form priming which has so far only been reported once in the literature on morphological processing, and only in a monolingual context (see Duñabeitia, Kinoshita, Carreiras, & Norris, 2011). Experiments 3 and 4 were thus conducted to investigate whether the participants of Experiments 1 and 2 also show large amounts of priming across all conditions in their other known language, German. The present experimental design, whereby both semantic and morphological relationships between primes and targets are manipulated in order to form conditions of a transparent (of the *hunter-hunt* type), opaque (of the *corner-corn* type) and form (of the *freeze-free* type) type, has not yet been implemented for the German language. However, several studies have studied morphological processing in German. For example, in their first experiment, Smolka, Komlosi, and Rösler (2008) manipulated the semantic and morphological relationship of German prefixed verbs. The target verb *kommen* (come) was either paired with primes that were both semantically and morphologically related (*mitkommen* – come along), only morphologically related (*umkommen* – perish), or only semantically related (*nahen* – approach). Results revealed that both transparent and opaque prefixed verbs prime their respective targets to a similar degree (40ms and 35ms, respectively), whereas semantically but not morphologically related primes only prime their respective targets minimally (9ms). Further evidence for robust morphological priming in German comes from a study by Smolka, Zwitserlood, and Rösler (2007), who demonstrated that both regular (e.g., *gezähmt* – *zahm*; tamed – tame) as well as irregular past participle verbs (e.g., *gesponnen –spinnen*; spun - spin) result in significant priming of their associated targets (50ms and 52ms, respectively). Interestingly, illegally formed past participle primes of a regular (e.g., *gezahmt*) and irregular (e.g., *gesponnt*) type also resulted in significant facilitation of their targets (33ms and 30ms, respectively). It thus appears that the morphological status of the prime significantly aids target recognition in the German language. It can therefore be reasonably assumed that Experiments 3 and 4 will demonstrate reliable priming for transparent items. However, it is unclear whether opaque suffixed primes and form control items will produce priming similar to the pattern demonstrated by Rastle, Davis, and New (2004) or to the pattern shown in Experiments 1 and 2. Experiments 3 and 4 therefore investigated morphological priming in German L1 (Experiment 3) and L2 (Experiment 4) speakers.

7.2 Experiment 3: German (L1) – English (L2) Bilinguals

7.2.1 Method

7.2.1.1 Stimuli

Ninety suitable prime-target pairs (see Appendix 4 for a complete list) were selected from the German CELEX 2 database (Baayen, Piepenbrock, & Gulikers, 1995). The design of the experiment mirrored that of Experiment 1 and 2, consisting of a transparent, opaque and form condition, with a related and control prime for each of the three conditions. Examples for prime types and conditions are provided in Table 14.

Table 14. Examples of prime-target pairs for Experiments 3 (German as L1) and 4 (German as L2), for the transparent, opaque and form condition.

	Transparent	*Opaque*	*Form*
Related prime -target	zauberer – ZAUBER (magician – magic)	bildung - BILD (education – picture)	krampf - KRAM (cramp - stuff)
Control prime - target	schlucht - ZAUBER (gorge – magic)	fenster – BILD (window – picture)	spinat – KRAM (spinach - stuff)

Across conditions, primes and targets were matched as closely as possible on frequency, neighbourhood size, letter length and overlap (see Table 15). However, despite careful item selection, the letter length of primes could not be matched perfectly between conditions. Primes in the form condition were on average one letter shorter than primes in the opaque and transparent condition. As outlined in Chapter 4, the majority of all German words are morphologically complex and few words in the language corpus as a whole are monomorphemic. Thus, by the nature of the German language, the rarer monomorphemic primes in the form condition are therefore shorter in length. To ensure that any effects of length on reaction latencies were captured in the results, target and prime length were treated as covariates in the analysis.

Suffix frequencies for words in the opaque and transparent condition were compiled by counting the total number of words containing each suffix in the morphological category of the CELEX2 (Baayen et al., 1995) database. This frequency count does not account for pseudomorphological endings, such as found in items of the opaque condition. As shown in Table 15, there was no significant difference in the suffix frequencies between the opaque and transparent condition.

Table 15. Comparison of measures across conditions for Experiment 3 and 4.

Measure	**Form**	**Opaque**	**Transparent**	**ANOVA**
Target Frequency*	0.96	1.07	1.22	F(2,89)=1.047, p>0.05
Raw Target Frequency	*27*	*69*	*34*	
Related Prime Frequency*	0.75	0.87	0.62	F(2,89)=1.030, p>0.05
Raw Related Prime Frequency	*16*	*27*	*10*	
Control Prime Frequency*	0.76	0.86	0.64	F(2,89)<1, p>0.05
Raw Control Prime Frequency	*15*	*25*	*12*	
Target Length	4.77	5.10	5.17	F(2,89)=1.810, p>0.05
Related Prime Length	6.47	7.23	7.17	F(2,89)=4.400, p<0.05
Control Prime Length	6.47	7.23	7.17	F(2,89)=4.400, p<0.05
Target Neighbourhood	2.57	2.47	2.10	F(2,89)<1, p>0.05
Related Prime Neighbourhood	0.70	1.07	1.17	F(2,89)=1.332, p>0.05
Control Prime Neighbourhood	1.03	0.70	0.83	F(2,89)>1, p>0.05
Related Prime-Target Letter Overlap	0.74	0.71	0.72	F(2,89)=1.231, p>0.05
Control Prime-Target Letter Overlap	0.74	0.71	0.72	F(2,89)=1.275, p>0.05
Suffix Frequency	n.a.	1055	1217	t(54.884)=-0.696, p>0.05

**Log per million*

All items were selected according to the same criteria outlined for Experiment 1 in Chapter 6. Thus, prime-target pairs in the form condition neither shared a semantic nor morphological relationship with each other, and non-overlapping prime endings formed non-suffix type strings in German, such as *pf, b,* or *ip*. In the opaque condition, prime-target pairs only shared an apparent morphological relationship with each other, but were not semantically related. Item pairs in the transparent condition shared both a semantic as well as morphological relationship with each other. Non-words were constructed as described for Experiment 1.

7.2.1.2 Procedure

The procedure was identical to that of Experiments 1 and 2 presented in Chapter 6.

7.2.1.3 Participants

All participants who took part in Experiment 2 (Chapter 6) also participated in Experiment 3.

7.3 Results

Data were analysed as described for Experiments 1 and 2 (Chapter 6), with the addition that target and prime letter length were treated as covariates in the item analysis. Errors made (239 of 3600 data points) were excluded. Data were cleaned and only RTs between 100ms and 2000ms were included in the analysis, resulting in the removal of 4 out of 3361 data points. No items needed to be removed from the analysis. Mean RTs and SDs for Experiment 3 are presented in Table 16.

Table 16. Experiment 3 - German as L1 for German L1 - English L2 bilinguals. Mean Reaction Time (RT) in milliseconds, Standard Deviation (SD) and Priming Magnitude per Condition.

	Transparent (SD)	*% Error*	*Opaque (SD)*	*% Error*	*Form (SD)*	*% Error*
Related prime	674 (197)	3	725 (240)	4.5	754 (250)	6.7
Control prime	724 (217)	4	731 (225)	5.2	770 (256)	7.8
Priming effect	*50*	*1*	*6*	*0.7*	*16*	*1.1*

The main effect of condition approached significance over participants and was significant over items [$F_1(2,76)=2.89$, $p=0.062$; $F_2(2,78)=3.40$, $p<0.05$]. Post-hoc Bonferroni corrected comparisons showed that transparent items (M=699) were responded to faster than form items (M=762) (all $ps<0.05$). Planned comparisons (significant over participants only) also showed that transparent items were responded to faster than opaque items (M=728) [$t_1(39)=3.75$, $p<0.01$; $t_2(58)=1.591$, n.s.] and that opaque items were responded to faster than form items [$t_1(39)=3.83$, $p<0.0001$; $t_2(58)=1.40$, n.s.]. Further, analyses revealed a significant main effect of prime type over participants [$F_1(1,38)=8.82$, $p<0.01$; $F_2(1,78)=1.35$, n.s.][8], with targets preceded by related items resulting in shorter reaction latencies than targets preceded by control primes. In addition, there was a significant interaction between the two main effects over participants only [$F_1(2,76)=32.57$, $p<0.0001$; $F_2(2,78)=2.20$, n.s.]. As can be seen in Figure 14, targets preceded by related primes were responded to fastest in the transparent condition, resulting in a very large priming effect (50ms) in this condition only. Priming in the opaque condition was minimal (6ms) and moderate in the form condition (16ms). However, the robustness of the interaction between condition and prime should be regarded with some caution. In fact, when priming magnitude is treated as a dependent

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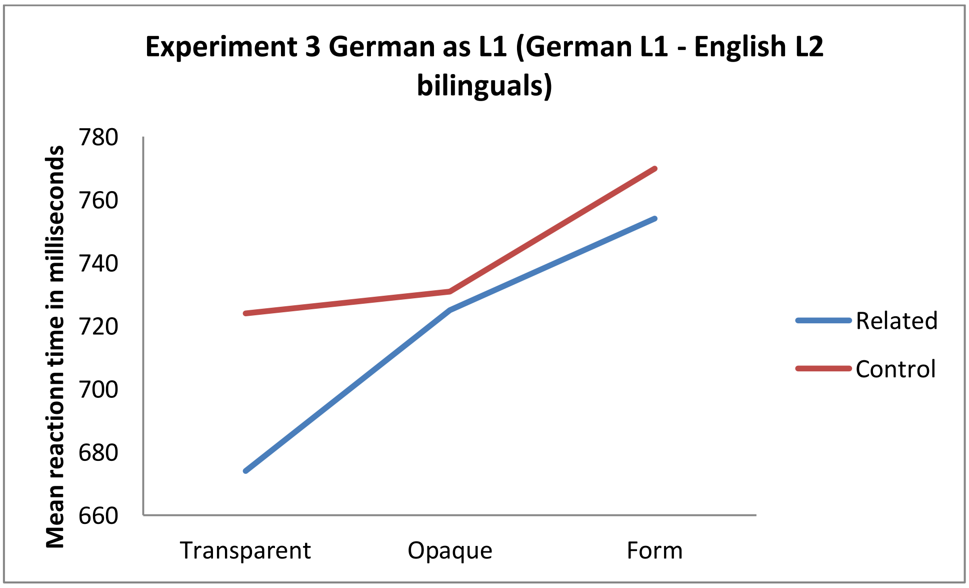
[8] When the analyses are performed without the covariates, the effect of prime is significant over items [$F_2(1,80)=9.270$, $p<0.01$].

variable, again, the effect is only significant over participants [F1(2,78)=32.02, $p<0.001$; F(2,78)=2.12, n.s.], showing more priming in the transparent than both the form [$t_1(39)=-7.215$, $p<0.001$], and opaque condition [$t_1(39)=6.27$, $p<0.001$] for participants. The covariates of target length [F(1,78)<1, n.s.] and prime length [F(1,78)<1, n.s.] were not significant, indicating that the difference in word length between conditions did not influence reaction latencies significantly.

Figure 14. Mean reaction times for German as L1 for related and control primes across the transparent, opaque and form condition.



Errors

Errors analyses revealed a significant main effect of condition [$F_1(2,76)=20.88$, $p<0.0001$; $F_2(2,78)=4.37$, $p<0.05$]. Post-hoc Bonferroni comparisons showed that more errors were made to form than transparent items ($p<0.01$). Planned comparisons (significant over participants only) also showed that more errors were made in the form compared to the opaque [$t_1(39)=3.62$, $p<0.01$; $t_2(58)=1.588$, n.s.], and in the opaque compared to the transparent condition [$t_1(39)=2.76$, $p<0.01$;

$t_2(58)=1.28$, n.s.]. The number of errors made was not affected by prime type [$F_1(1,38)=2.02$, n.s.; $F_2(1,78)<1$, n.s.], and there was no interaction between the main effects [$F_1(2,76)<1$, n.s.; $F_2(2,78)<1$, n.s.].

In summary, the findings of Experiment 3 demonstrate that in German, German L1 – English L2 speakers show a numerically large priming effect in the transparent condition. In other words, primes that are both morphologically and semantically related to their respective targets appear to aid target recognition. On the other hand, primes with an apparent morphological but no semantic relationship to their respective targets do not appear to aid target recognition. With regards to form items, primes that are neither morphologically nor semantically related to their respective primes result in a moderate facilitation effect. However, in the absence of a significant effect of priming over items, these results should be regarded as an indication of a trend, rather than a robust effect.

7.4 Experiment 4 – English (L1) – German (L2) Bilinguals

7.4.1 Methods

The stimuli and procedures were identical to Experiment 3.

7.4.1.1 Participants

All participants who took part in Experiment 1 (Chapter 6) also participated in Experiment 4. Participants' bilingual status and knowledge of the German language was assessed prior to taking part in Experiment 4 (see Chapter 11 for analyses and discussion of the bilingual assessment). On average, participants first learnt German aged 10 (range 0 – 17), and were comfortable speaking German aged 14 (range 0 – 25).

7.4.2 Results

Data were analysed as described for Experiments 1 and 2 (Chapter 6), with the addition that target and prime letter length were treated as covariates in the item analysis. Reaction time data were cleaned and errors removed (401 of 2340 data points). Only RTs between 100ms and 2000ms were included in the analysis, resulting in the removal of a further 34 data point. Items to which more than half the participants made errors were removed. This resulted in the removal of five form, two opaque, and two transparent items[9] [10]. Mean RTs and standard deviations are presented in Table 17. Although error rates are high, they are in line with other studies using bilingual participants (e.g., Portin et al., 2008).

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[9] Analyses were also conducted including all items. The removal of these items did not alter the results significantly.

[10] The following items were removed: form: scharf-SCHAR, spritze-SPRIT, flaum-FLAU, kolosseum-KOLOSS, schamott-SCHAM; opaque: muffel-MUFF, breit-BREI; transparent: kiesel-KIES, wirrsal-WIRR

Table 17. Experiment 4 – German as L2 in English L1 – German L2 bilinguals. Mean Reaction Time (RT) in milliseconds, Standard Deviation (SD) and Priming Magnitude per Condition.

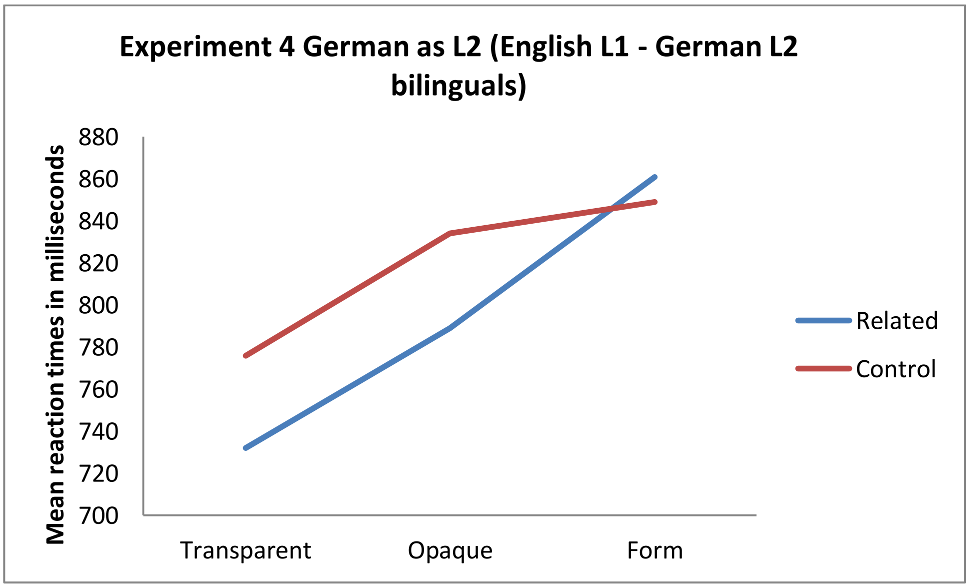
	Transparent (SD)	*% Error*	*Opaque (SD)*	*% Error*	*Form (SD)*	*% Error*
Related prime	732 (247)	8.7	789 (269)	10.7	861 (331)	18.5
Control prime	776 (254)	8.6	834 (294)	11.8	849 (282)	19.3
Priming effect	*44*	*-0.1*	*45*	*1.1*	*-12*	*0.8*

Analyses revealed a significant main effect of condition [$F_1(2,48)=31.48$, $p<0.0001$; $F_2(2,73)=6.78$, $p<0.01$]. Bonferroni post-hoc tests showed that transparent items were responded to faster than form items ($p<0.01$). Planned comparisons also demonstrated that form items (significant over participants only) were responded to significantly slower than items in the opaque condition [$t_1(25)=3.20$, $p<0.01$; $t_2(51)=1.61$, n.s.], and that opaque items were responded to slower than transparent items [$t_1(25)=4.86$, $p<0.0001$; $t_2(51)=2.02$, $p<0.05$]. Further, analyses showed a significant main effect of prime type over participants [$F_1(1,24)=14.23$, $p<0.01$; $F_2(1,73)<1$, n.s.], demonstrating that targets preceded by related primes were responded to faster than targets preceded by control primes.

In addition, there was a significant interaction between the two main effects [$F_1(2,48)=4.64$, $p<0.05$; $F_2(2,73)=2.98$, $p=0.57$]. Further analyses with priming magnitude as dependent variable [$F1(2,50)=3.10$, $p=0.054$; $F_2(2,78)=3.17$, $p<0.05$] showed this effect to be significant between the form and transparent condition only [$t_1(25)=-2.01$, $p=0.056$; $t_2(51)=-2.12$, $p<0.05$], with greater priming in the transparent than in the form condition; the effect approached significance between the form and opaque condition [$t_1(25)=-1.87$; $p=0.073$; $t2(51)=-1.97$, $p=0.055$], indicating more priming in the opaque compared to the form condition (see also

Figure 15). The covariates of target length [F(1,73)<1; n.s.] and prime length [F(1,73)=1.43, n.s.] were not significant.

Figure 15. Mean reaction times for German as L2 for related and control primes across the transparent, opaque and form condition.



Errors

Error analyses showed a significant main effect of condition [$F_1(2,48)=23.82$, $p<0.0001$; $F_2(2,73)=5.53$, $p<0.05$]. Bonferroni post-hoc tests showed that more errors were made to form than transparent items ($p<0.01$). Planned contrasts also demonstrated that form items drew more errors compared to opaque items [$t_1(25)=6.20$, $p<0.001$; $t_2(58)=2.14$, $p<0.05$], and that opaque items also drew more errors than transparent items (significant over participants only) [$t_1(25)=3.06$, $p<0.01$; $t_2(58)=0.61$, n.s.]. There was no effect of prime type on the number of errors made [$F_1(2,24)<1$, n.s.; $F_2(1,73)<1$, n.s.], and there was no interaction between the two main effects [$F_1(2,48)<1$, n.s.; $F_2(2,73)<1$, n.s.].

In summary, Experiment 4 demonstrated that English L1 - German L2 speakers showed a priming pattern in German more akin to that demonstrated by Rastle et al. (2004), with comparable facilitation effects for transparent and opaque items. Experiment 4 further showed some moderate inhibition for form control items.

7.5 Comparison Experiment 3 and 4

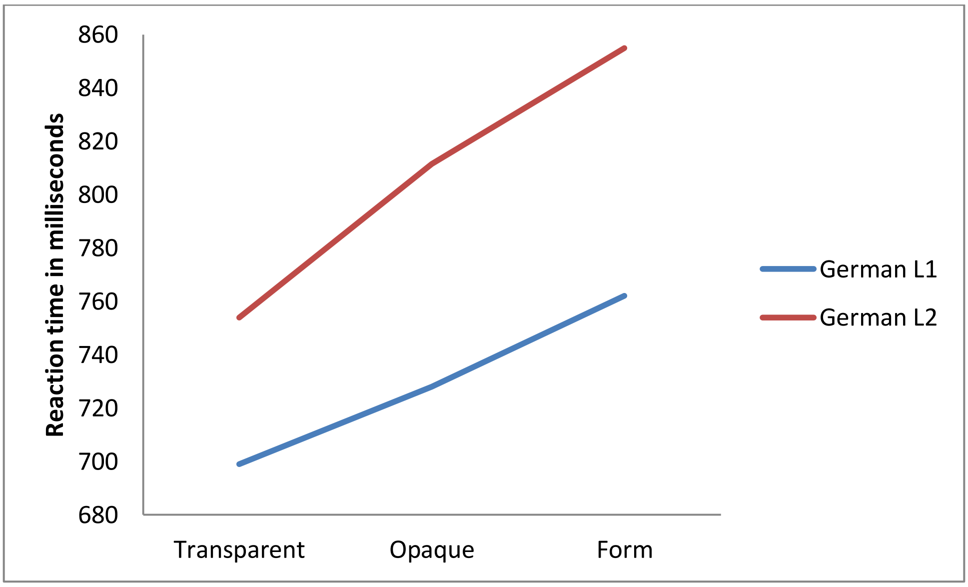
The cleaned data files of Experiments 3 and 4 were combined. Items that had previously been deleted in one but not the other file were removed for the combined file. Results were analysed using a mixed model analysis (for a comparison between Experiment 3 and 4, see Figures 14 and 15) as described in Chapter 6.

7.5.1 Results

Mixed model analyses with DJMIXED showed a significant main effect of condition [F(2,5190)=63.43, p<0.001]. Further analyses revealed that overall, transparent items were responded to faster than both opaque [F(1,3548)=30.62, p<0.001] and form items [F(1,3412)=113.57, p<0.001]. Opaque items were also responded to faster than form items [F(1,3354)=27.13, p<0.001]. Further, there was a significant effect of prime [F(1,5191)=13.25, p<0.01], demonstrating that targets preceded by related primes were responded to faster than targets preceded by control primes.

Further, there was a significant interaction between condition and prime [F(2,5190)=3.96, p<0.05], indicating that across both groups, priming magnitude varied as a function of condition. In particular, compared to German L1 speakers, there was more priming for German L2 speakers in the opaque condition. This is also demonstrated in Figure 17 (see p. 169). There was a significant main effect of native language [F(1,66)=9.88, p<0.01], with German L1 speakers making faster overall lexical decisions (M=718ms) than German L2 speakers (M=803ms). Thus, on average, German L1 speakers were 85ms faster in making lexical decisions compared to German L2 speakers. Further, there was a significant interaction between language and condition [F(2,5190)=4.30, p<0.01]. As can be seen in Figure 16, transparent items were responded to fastest by German L1 speakers, whereas form items were responded to slowest by German L2 speakers. Overall, both German L1 and L2 speakers responded fastest to transparent and slowest to form items.

Figure 16. Reaction times in milliseconds for German as L1 and L2 collapsed across conditions.



Errors

Error analyses demonstrated a significant main effect of condition [$F(2,82)=6.16$, $p<0.001$]. Further analyses showed that overall, fewer errors were made in the transparent compared to the form condition [$F(1,52)=9.33$, $p<0.01$]. In addition, there was a significant effect of native language [$F(1,66)=16.27$, $p<0.001$] demonstrating that more errors were made by German L2 compared to German L1 speakers. The interaction between condition and native language was significant [$F(2,5161)=2.99$, $p=0.05$], with German L2 speakers making more errors particularly in the form and opaque conditions.

7.6 DISCUSSION

The purpose of Experiments 3 and 4 was to investigate whether morphological processing in bilingual German L1 and L2 speakers yields priming patterns akin to those demonstrated by Rastle et al. (2004), with large priming effects for transparent and opaque items, but minimal form priming effects; or whether in German, results are similar to those of Experiments 1 and 2 (Chapter 6), with comparable priming magnitudes across all conditions.

For German L1 speakers, the results demonstrated a large priming effect for transparent items (50ms), negligible priming for opaque items (6ms), and a moderate form priming effect (16ms). Overall, targets preceded by related primes were responded to faster than targets preceded by control primes; this was particularly the case in the transparent condition. The results for German native speakers potentially indicate that the combination of both a semantic and morphological relationship between target and prime leads to more facilitation than achieved in the presence of a morphological relationship alone. This contrasts with other findings obtained with prefixed German verb primes (e.g., Smolka et al., 2008), which demonstrated comparable priming effects between transparent and opaque items. However, given the absence of a significant F2 effect of priming in the ANOVA analysis[11], the results should be regarded as trends, rather than robust effects. Further, differences in the methodology between the Smolka et al. (2008) study and the present experiment (e.g., the type of prime (prefix versus suffix, respectively), and SOA (300ms versus 43ms, respectively) may to some extent

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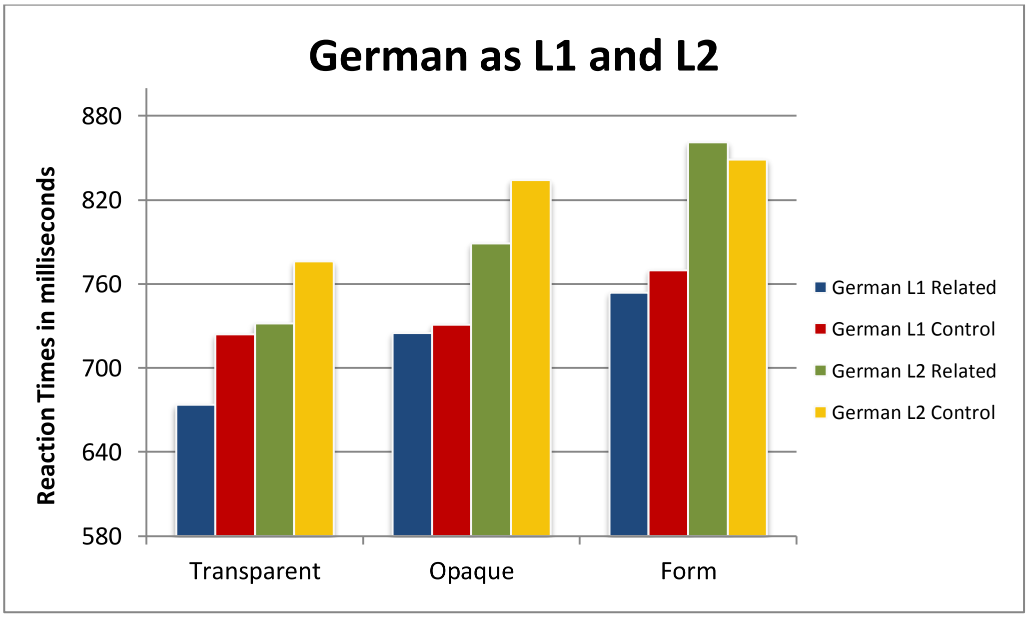
[11] If covariates are included in the analysis

account for the difference in findings. For German L2 speakers, the priming pattern observed in Experiment 4 did not follow the trend observed for German L1 speakers. Rather, German L2 speakers showed comparably large priming effects in both the transparent (44ms) and the opaque (45ms) condition, and moderate inhibition for form items (-12ms). The inhibition effect of orthographically similar items has previously also been reported for German (Smolka et al., 2008; Experiment 2). Overall, the pattern obtained is more comparable to that described by Rastle et al. (2004), with comparable priming patterns for both transparent and opaque items.

In comparing German L1 and L2 speakers, it appears that the two groups follow a similar pattern with respect to overall reaction times in relation to each condition. Both L1 and L2 speakers responded fastest to transparent and slowest to form items (see Figure 17).

Figure 17. Reaction times (in ms) to related and control primes in the transparent, opaque, and form condition for German as L1 and L2.



The results of Experiments 3 and 4 demonstrated that bilingual speakers of German and English do not show identical morphological processing in their respective languages. Rather, there may be distinct, and possibly language-dependent differences in how English and German morphologically complex items are processed. Specifically, Experiments 1 and 2 showed large facilitation effects across all conditions for both English L1 and L2 speakers. This trend was not replicated to the same extent in German, particularly in relation to the large form priming effects obtained in Experiments 1 and 2. Thus, the question remains why neither English L1 nor L2 speakers demonstrated the priming patterns widely reported for English in the literature, with large transparent, moderate to large opaque, and minimal form priming effects. One factor often ignored in the morphological priming literature is that of prime frequency (except for McCormick et al., 2009; but see Chapter 8). In particular, prime frequency may play a role in bilingual visual word processing due to differences in exposure and age of acquisition of a wide range of words. Experiments 5 (Chapter 8) and 6 (Chapter 9) were thus designed to investigate whether prime frequency significantly influences the magnitude of both morphological and form priming in early bilingual visual word processing.

Chapter 8

Frequency Effects on Morphological Processing in English Native Speakers

8.1 Introduction

The surprising results from the experiments thus far, particularly pertaining to the English language (Experiments 1 and 2), relate to strong priming effects obtained in the form condition. One possible confound in relation to bilingual visual word processing is that of prime frequency. By the nature of their dual-language status, bilingual speakers have been exposed less frequently to certain words, particularly, but not exclusively, in their L2. Thus, the relative exposure to and perceived frequency of a variety of words is likely to differ between native and second language speakers. Given this potential confound in perceived word frequency between L1 and L2 speakers, and the patterns of results obtained, it is important to study the role of prime frequency further. Another possible confound relates to the relative prime-target frequency in relation to the form items of Experiments 1 and 2. Specifically, compared to opaque and transparent items, form targets were somewhat higher in frequency than their respective primes. Thus, the variable of prime frequency in relation to morphological processing was explored in Experiment 5, in order to study its contribution to the priming pattern obtained in Experiments 1 and 2.

The variable of prime frequency has only received limited attention in the morphological priming literature, although it is well established that the speed of target processing is influenced by the relative frequencies of masked orthographic primes in relation to their targets. For example, using 4-letter prime-target pairs (e.g., *char-CHAT*) in which primes were semantically unrelated orthographic neighbours of the targets, Segui and Grainger (1990) demonstrated that high-frequency masked primes (SOA of 60ms) inhibit the recognition of lower-frequency targets, whereas lower-frequency primes tend to facilitate recognition of higher-frequency targets. Similar effects have been reported in Spanish (Carreiras, Perea, & Grainger, 1997), English (Davis & Lupker, 2006; Nakayama, Sears, & Lupker, 2008), and Dutch (De Moor, Van der Herten, & Verguts, 2007). By means of an incremental priming technique, the latter study demonstrated that the inhibition effect increased as a function of SOA, as long as the prime remained masked (Segui & Grainger, 1990, observed that the inhibition effect disappears with an SOA of 350ms when the prime is clearly visible).

One of the few studies in the morphological priming literature addressing the effects of prime frequency was reported by McCormick, Brysbaert, and Rastle (2009). In this study, transparent morphological primes ranged from frequencies four times higher than targets (*equipment-EQUIP*) to prime frequencies four times lower than targets (*harassment-HARASS*). The authors reported comparable priming magnitudes for both frequencies (24 ms vs. 27 ms), indicating that masked morphologically related primes facilitate target processing regardless of their frequency. As the study did not include opaque primes, this raises the question whether prime frequency is irrelevant for opaque primes as well. Indeed, the facilitation of high-frequency opaque primes seems uncertain in the light of the orthographic inhibition effect observed by Segui and Grainger (1990) and others. However, the primes used by Segui and Grainger (1990) differed in only one letter (often in the beginning or the middle of the word), and are thus quite different from the more complex word primes of the transparent and opaque condition. Thus, the question remains whether an apparently complex high-frequency prime, such as *candidate* would prime the target word *candid* to the same extent as the low-frequency prime *fabricate* primes *fabric*.

Given the potential confound in perceived word frequency between L1 and L2 speakers, and the above findings relating to the effects of prime frequency (e.g.,De Moor et al., 2007; Segui & Grainger, 1990), Experiment 5 was designed to investigate whether prime frequency plays a contributing role in morphological processing across the transparent, opaque, and form control conditions, and whether prime frequency can account for some of the observed patterns in the experiments described in Chapter 6. As there is no L1 opaque baseline measure against which the contribution of prime frequency in L2 speakers can be measured (the study by McCormick et al., 2009, did not include frequency manipulations for opaque and form items), Experiment 5 was conducted with native English speakers only. Thus, Experiment 5 manipulated the prime frequencies for transparent and opaque morphological primes, as well as non-morphological form primes, whilst holding the target frequency constant at a medium frequency level.

8.2 Experiment 5 – English L1

8.2.1 Method

8.2.1.1 Stimuli and Apparatus

Three hundred and fifty prime-target pairs were selected from the British National Corpus (BNC; available at http://www.natcorp.ox.ac.uk/) and the CELEX English database (Baayen, Piepenbrock, & van Rijn, 1995) to form three conditions of form (130 pairs), opaque (90 pairs), and transparent (130 pairs) items. As for Experiments 1 to 4, in the form condition, primes and targets shared neither a semantic nor morphological relationship (e.g., *spinach-spin*). In the opaque condition, primes and targets shared no semantic relationship, but shared an apparent morphological relationship (i.e. the primes were parsable into stem + suffix; e.g., *corner-corn*). Pairs in the transparent condition shared both a semantic and morphological relationship, (e.g., *hunter-hunt*). Whilst the frequency of the targets was held constant across all three conditions (*M = 12.5 per million*; frequencies based on the BNC), the frequencies of the word primes were varied. Prime frequencies ranged from low to high (range 1-488), and were selected in such a way that each condition contained 30 primes lower in frequency than their respective targets, 30 primes of a similar frequency to their respective targets, and 30 primes higher in frequency than their respective targets.

In addition, and akin to the transparent condition in the McCormick et al. (2009) study, for the form and transparent condition, 40 *non-word* prime-target pairs each were devised (form: *dripose - drip*; transparent: *blastize – blast*). Non-word primes in both of these conditions used endings matched as much as possible to those used for the word primes (e.g., *jumpow -jump*, analogous to *yellow-yell* in the form condition; and *buncher – bunch*, analogous to *blender-blend* in the transparent condition). Non-word primes could not be developed for the *opaque* prime-type condition because the only way in which a morphologically-structured non-word can be interpreted is in terms of the *transparent* combination of its components (e.g., vasper -> someone who vasps).

Examples of the stimuli in the different conditions are presented in Table 18 and the full list is shown in Appendix 5.

Table 18. Example of prime-target pairs for form, opaque, and transparent items.

	Form	**Opaque**	**Transparent**
Non-word Prime	hoverid-HOVER vs. clapid-HOVER		beastage-BEAST vs. stuckage-BEAST
*Low frequency Prime**	mildew-MILD vs. crutch-MILD	leverage-LEVER vs. blockage-LEVER	kneeling-KNEEL vs. blurring-KNEEL
Medium frequency Prime	dialect-DIAL vs. boycott-DIAL	casualty-CASUAL vs. vicinity-CASUAL	moisture-MOIST vs. treasure-MOIST
High frequency Prime	yellow-YELL vs. attend-YELL	message-MESS vs. package-MESS	election-ELECT vs. religion-ELECT

*Frequencies over 0.

Prime-target pairs were matched as closely as possible on frequency, length, neighbourhood size, prime-target letter overlap, and suffix endings (in the *opaque* and *transparent* conditions only), with information about frequency and neighbourhood size drawn from the N-Watch database (Davis, 2005) (see also Tables 19-21)[12]. A further 350 primes were selected to function as unrelated control

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[12] Although primes and targets were matched very well across all frequencies in the form and opaque condition, target and prime length could not be matched perfectly for transparent primes

primes for each target. Control primes were semantically unrelated to the related primes and targets, shared no letter in the same position, and were matched on frequency, length and neighbourhood size to the related primes. Where possible, in the opaque and transparent conditions, control primes contained the same suffix ending as the corresponding related prime. For the *non-word* primes, the control prime contained the same ending as the corresponding related prime.

Table 19. Comparison of measures for form items Experiment 5.

	Low Frequency	Medium Frequency	High Frequency	ANOVA
Target Frequency	13.8	10.9	9.8	F(2,87)=1.590, p>0.05
Related Prime Frequency	1.3	11.4	120.4	F(2,87)=43.781, p<0.001
Control Prime Frequency	1.3	12	121.1	F(2,87)=50.576, p<0.001
Target Neighbourhood	3.8	3.5	2.8	F(2,87)=1.693, p>0.05
Related Prime Neighbourhood	0.5	1	1	F(2,87)=1.571, p>0.05
Control Prime Neighbourhood	0.3	0.7	0.9	F(2,87)=1.457, p>0.05
Target Length	4.5	4.5	4.6	F(2,87)<1
Related Prime Length	6.9	6.9	6.9	F(2,87)<1
Control Prime Length	6.9	6.9	6.9	F(2,87)<1
Letter Overlap	0.7	0.7	0.7	F(2,87)<1

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across all frequencies. Low frequency primes and targets tended to be one letter shorter than high frequency primes and targets. However, the proportional letter overlap did not differ between frequencies. Thus, target and prime lengths, as well letter overlap, and prime – target letter differences were treated as covariates in the analysis.

Table 20. Comparison of measures for opaque items Experiment 5.

	Low Frequency	Medium Frequency	High Frequency	ANOVA
Target Frequency	14.4	12.9	10.9	F(2,87)<1
Related Prime Frequency	1.4	10.7	144	F(2,87)=48.735, p<0.001
Control Prime Frequency	1.5	10.6	118	F(2,87)=49.042, p<0.001
Target Neighbourhood	3.3	3.2	2.7	F(2,87)<1
Related Prime Neighbourhood	0.6	0.7	0.9	F(2,87)<1
Control Prime Neighbourhood	0.4	0.8	0.9	F(2,87)=1.78, p>0.05
Target Length	5.1	5.1	4.8	F(2,87)=1.492, p>0.05
Related Prime Length	7.3	7.2	7	F(2,87)<1
Control Prime Length	7.3	7.2	7	F(2,87)<1
Letter Overlap	0.7	0.7	0.7	F(2,87)<1
Suffix Frequency	651	548	706	F(2,87)<1

Table 21. Comparison of measures for transparent items Experiment 5.

	Low Frequency	Medium Frequency	High Frequency	ANOVA
Target Frequency	11.5	13.5	13	F(2,87)<1
Related Prime Frequency	1.4	15.3	87.6	F(2,87)=22.017, p<0.001
Control Prime Frequency	1.3	14.2	72.1	F(2,87)=45.512, p<0.001
Target Neighbourhood	2.7	2.1	1.8	F(2,87)=1.423, p>0.05
Related Prime Neighbourhood	0.7	0.7	0.4	F(2,87)<1
Control Prime Neighbourhood	1	0.4	0.4	F(2,87)=2.774, p>0.05
Target Length	5.1	5.8	5.8	F(2,87)=5.349, p<0.01
Related Prime Length	7.2	8.3	8.2	F(2,87)=6.939, p<0.01
Control Prime Length	7.2	8.3	8.2	F(2,87)= 6.939, p<0.01
Letter Overlap	0.7	0.7	0.7	F(2,87)<1
Suffix Frequency	822	603	894	F(2,87)<1

Non-word targets (350 trials) were composed by changing one or two letters of a new set of selected words. The non-word targets were matched to the word targets on length and neighbourhood size. Half the non-word targets were preceded by an orthographically related and half by an unrelated word prime.

All stimuli were randomly assigned to two lists, whereby in each list the target appeared only once, paired either with the related or the control prime. Each participant was randomly assigned to one of these lists, and thus saw each target and prime only once. Random presentation of stimuli and response recording was controlled by DMDX software (Forster & Forster, 2003).

8.2.1.2 Procedure

Participants were tested on a Pentium III personal computer in a quiet room. They were instructed that they would see letter strings on the computer screen, to which they had to decide as quickly and accurately as possible, using a two-button box ('yes' response controlled with the dominant hand), whether the word was an existing English word or not. The participants were not told about the presence of the primes. Following a fixation point *, each prime was preceded by a 500ms forward hash mark mask (###########), completely masking the prime. Primes were presented in lowercase for 42ms and immediately followed by the target in uppercase, which remained on the screen until a response was made. Participants received both verbal and written instructions and 10 practice trials prior to commencing the experiment.

8.2.1.3 Participants

Sixty students from Royal Holloway, University of London, volunteered to participate, and were paid £8 for their time. All participants were native speakers of English and had normal or corrected-to-normal vision.

8.2.2 Results

Reaction times (RTs) and correct responses were collected for all participants; all incorrect responses were removed from the RT analyses (6.5%), and RTs below 100ms and above 2000ms were discarded (0.2% of data). Seven form and four opaque targets were excluded from the analysis due to error rates over 50%[13]. Reaction times (collapsed over frequency) and percentages of errors are shown in Table 22. In addition to ANCOVA analyses, two mixed model analyses were also performed. In the ANCOVAS, prime frequency was treated as a fixed factor with three levels (low, medium, high), whereas in the mixed model analysis, prime frequency was treated as a continuous fixed variable (predictor variable).

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[13] These were: form: untold-UNTO, gallop-GALL, believe-BELIE, charge-CHAR, contract-CONTRA, though-THOU, tongue-TONG; opaque: basalt-BASAL, battle-BATT, discuss-DISCUS, routine-ROUT

Table 22. Experiment 5 (English) – English native speakers. Results collapsed over frequency. Reaction times (in milliseconds), SDs (in ms), and percentage of errors.

		Condition								
		Form			Opaque			Transparent		
	Prime	*M*	*SD*	*% error*	*M*	*SD*	*% error*	*M*	*SD*	*% error*
Non-Word	Related	630	176	3.6				632	176	2.4
	Control	658	195	4.8				649	172	3.3
	Priming effect	*28*		*1.2*				*17*		*0.9*
Word Primes	Related	673	203	7.0	663	208	8.0	632	198	2.6
	Control	679	210	7.8	676	208	7.3	657	199	3.7
	Priming effect	*6*		*0.8*	*13*		*-0.7*	*25*		*1.1*

8.2.2.1 ANCOVA Analyses

ANCOVAs were performed as described in Chapter 4. Two separate analyses were performed, one ANCOVA for word type primes, and one ANOVA for non-word type primes. For word type primes, fixed factors were: condition (transparent, opaque, form), prime type (related, control), frequency (low, medium, high), and list (two levels). Covariates were target and prime length, in order to account for any effects on RT due to differences in length between and across conditions. In addition, further covariates were prime-target letter overlap, and prime-target letter difference, to account for any potential effects of deletion and addition neighbours (e.g., *early-earl, locust-locus*) on RT. For non-word type primes ANOVA, fixed factors included condition (form type non-word, transparent type-non-word), prime type (related, control), and list (two levels). Results are presented in Table 23.

Table 23. Experiment 5 – English native speakers. Reaction times (in milliseconds), priming effects (in ms) and standard deviations (in ms) for condition by frequency by prime.

Condition	Frequency and prime	Mean	Priming	Std. Deviation
Form	*Low related*	651	*2*	189
	Low control	653		193
	Medium related	672	*29*	200
	Medium control	701		229
	High related	706	*-15*	219
	High control	691		206
Opaque	*Low related*	646	*13*	206
	Low control	659		206
	Medium related	661	*9*	208
	Medium control	670		188
	High related	686	*15*	208
	High control	701		231
Trans	*Low related*	613	*38*	182
	Low control	651		195
	Medium related	629	*14*	198
	Medium control	643		184
	High related	653	*25*	212
	High control	678		215

8.2.2.1.1 ANCOVA for word prime RTs

Results demonstrated a significant main effect of condition [$F_1(2,116)=55.84$, $p<0.001$; $F_2(2,239)=13.24$, $p<0.001$]. Post-hoc Bonferroni test showed transparent items were responded to faster than opaque and form items (all ps<0.05), which was also confirmed by planned comparisons [transparent and form [$t_1(59)=7.31$, $p<0.001$; $t_2(58)=2.61$, $p<0.05$]; transparent and opaque [$t_1(59)=10.46$, $p<0.01$; $t_2(58)=2.61$, $p<0.05$]]).

Further, there was a significant main effect of prime type over participants [$F_1(1,58)=42.28$, $p<0.0001$; $F_2(1,239)=1.02$, n.s.], demonstrating that targets preceded by related primes were responded to faster than targets preceded by control primes. It has to be noted here, however, that the effect over items becomes highly significant in the absence of the covariates [$F_2(1,242)=22.10$, $p<0.0001$]. In addition, there was a significant main effect of frequency, [$F_1(2,116)=70.69$, $p<0.001$; $F_2(2,239)=6.66$, $p<0.01$], indicating a graded process by which reaction time increased as a function of increasing frequency. Targets preceded by low frequency primes resulted in shorter reaction latencies than when targets were preceded by both medium [$t_1(59)=-4.49$, $p<0.001$; $t_2(58)-1.53$, n.s.] and high frequency primes [$t_1(59)=-11.26$, $p<0.001$; $t_2(58)=-3.38$, $p<0.01$]. Targets preceded by medium frequency primes also resulted in shorter reaction latencies compared to targets preceded by high frequency primes [$t_1(59)=-7.47$, $p<0.001$; $t_2(58)=-2.16$, $p<0.05$].

Further, there was a significant interaction between condition and prime type [$F_1(2,116)=3.287$, $p<0.05$; $F_2(2,239)=3.359$, $p<0.05$] (see also Table 22, p. 180), again, demonstrating a graded process, with little priming in the form condition (6ms), moderate priming in the opaque condition (13ms), and a larger priming effect in the transparent condition (25ms).

The interaction between condition and frequency was significant over participants only [$F_1(4,232)=3.93$, $p<0.01$; $F_2(4,239)=1.24$, n.s.]. As can be seen in Table 24, transparent items were responded to fastest across all frequencies. Form and opaque items only differed in the medium frequency range, in which opaque items were responded to faster than form items.

Table 24. Experiment 5 – English native speakers. Means and standard deviation (in milliseconds) for conditions of form, opaque and transparent, collapsed over relatedness.

Frequency	Condition	Mean	Std. Deviation
Low	*Form*	652	191
	Opaque	653	206
	Transparent	632	189
Medium	*Form*	687	215
	Opaque	666	198
	Transparent	636	191
High	*Form*	698	213
	Opaque	694	220
	Transparent	665	214

The interaction between prime type and frequency was not significant [$F_1(2,116)=1.64$, $p>0.05$; $F_2(1,139)<1$, n.s.]. However, the three way interaction between condition, prime type, and frequency was significant [$F1(4,232)=3.51$, $p<0.01$; $F2(4,239)=2.41$, $p=0.05$]. As can be seen in Table 23 (p. 181) in both morphological conditions, there is a considerable priming effect across all frequencies, though this is more pronounced for the transparent condition. In the form control condition, however, only medium frequency primes yield a priming effect comparable to that of the morphological conditions, whereas low frequency primes lead to negligible priming and high frequency primes to an inhibition effect.

None of the covariates reached significance (all $ps>0.05$), or interacted with any main effects (all $Fs<1$). Thus, the difference in prime and target length within and between conditions did not have any effect on reaction latencies.

Error Analyses

Error analyses revealed a significant main effect of condition [$F_1(2,116)=41.79$, $p<0.001$; $F_2(2,248)=8.24$, $p<0.001$]. Bonferroni post-hoc tests demonstrated that more errors were made in form and opaque condition than in the transparent condition (all ps<0.05), which was also demonstrated by planned comparisons (form and transparent [$t_1(59)=8.09$, $p<0.001$; $t_2(58)=3.65$, $p<0.01$]; opaque and transparent [$t_1(59)=7.62$, $p<0.001$; $t_2(58)=3.52$, $p<0.01$]). Also, there was a significant main effect of frequency [$F_1(2,116)=33.55$, $p<0.001$; $F_2(2,248)=4.56$, $p<0.05$], with more errors made in the high frequency compared to both the medium [$t_1(59)=-4.99$, $p<0.001$; $t_2(58)=-1.84$, $p<0.05$] and low frequency [$t_1(59)=-7.59$, $p<0.001$; $t_2(58)=-2.99$, $p<0.01$] condition. In addition, more errors were also made in the medium compared to the low frequency condition [$t_1(59)=-2.99$, $p<0.01$; $t_2(58)-1.28$, n.s.]. The interaction between condition and frequency was also significant over participants [F1(4,232)=9.96, $p<0.001$; F2(4,248)=1.23, n.s.], with more errors in the form and opaque condition when targets were preceded by medium and high frequency primes. All other factors and covariates were non-significant (all ps>0.05) and are not considered further.

8.2.2.1.2 ANOVA for non-word type primes

Results (for means see Table 23, p. 181) revealed a significant main effect of prime type only [$F_1(1,58)=29.09$, $p<0.001$; $F_2(1,78)=25.06$, $p<0.001$], demonstrating that targets preceded by related primes were responded to faster than targets preceded by unrelated primes. There was no significant main effect of condition

[$F_1(1,58)=1.12$, n.s.; $F_2(1,78)<1$], and no interaction between the main effects [all ps>0.05].

Errors

Error analyses showed a significant main effect of condition over participants, [$F_1(1,59)=5.31$, $p<0.05$; $F_2(1,78)=1.55$, n.s.], demonstrating that more errors were made in the form prime-type condition than in the transparent prime-type condition. In addition, there was a significant main effect of prime [$F_1(1,59)=4.50$, $p<0.05$; $F_2(1,78)=4.85$, $p<0.05$], demonstrating that more errors were made to targets preceded by control compared to related primes. The interaction between the main factors was not significant (all Fs<1).

8.2.2.2 Mixed Model Analyses

8.2.2.2.1 A mixed effects analysis of the word prime RTs

In order to fully explore the effect of prime frequency on decision latencies, a mixed effects analysis was performed. The analysis included fixed effects of condition (*form, opaque, transparent*) and prime relatedness (*related, control*), as well as their interaction. Further, random intercepts for participants and targets were included. The log frequencies of the primes and targets were treated as continuous variable, and were taken from the SUBTLEX database (Brysbaert & New, 2009), as they explained more variance in the priming effect ($R^2=0.223$) than those from the British National Corpus ($R^2=0.023$) [$F(3,266)=3.07$, $p<0.05$]. Analyses were performed in SPSS as outlined by Brysbaert (2007), as at present, the SPSS DJMIXED add on does not accommodate covariates.

The mixed effect analysis revealed a significant main effect of condition [F(2,286)=6.86, p<0.01], and prime relatedness [F(1,13980)=32.36, p<0.001]. Reaction times were faster for related than control primes. In addition there was a significant interaction between condition and prime relatedness [F(2,13918)=4.77, p<0.05], with the smallest priming effect for form primes (6ms), largest for transparent primes (25ms), and medium for opaque primes (13ms). Subsequent analyses indicated that the interaction between condition and prime relatedness was only reliable for form primes versus transparent primes [F(1,9312)=8.68, p=0.01], but not for form versus opaque primes [F(1,9002)=2.47, n.s.], and opaque versus transparent primes [F(1,9475)=2.08, n.s.]. Thus, mixed model analyses revealed a graded priming pattern, with most priming in the transparent condition, moderate priming in the opaque condition, and negligible priming in the form condition.

In addition, there was a clear effect of target frequency [regression weight of -80.0; t(247.981)= -11.55, p<0.001], and a just significant effect of prime frequency [regression weight of +6.0; t(1707)=1.98, p=0.048] with longer RTs as prime frequency increased. Although there was a significant effect of target and prime frequency on overall reaction times, further analyses demonstrated that there were no significant interactions between the discrete (condition) and continuous effects (target and prime frequency) (all ps>0.15), indicating that none of the priming effects changed significantly as a function of prime or target frequency. The absence of a significant interaction between prime frequency and priming is shown in Figures 18 - 20, where for the three different types of primes or conditions (form, opaque, transparent) the priming effect is plotted as a function of the prime frequency.

Figure 18. Form Condition. Amount of priming (related-control) plotted against LogSUBTlex related prime frequencies.

Figure 18 indicates that it is unlikely that the difference in priming magnitudes between frequencies was due to differences in prime frequency: the only effect that is apparent is that there is less priming for high-frequency primes than for low-frequency primes (as demonstrated by Segui and Grainger, 1990)

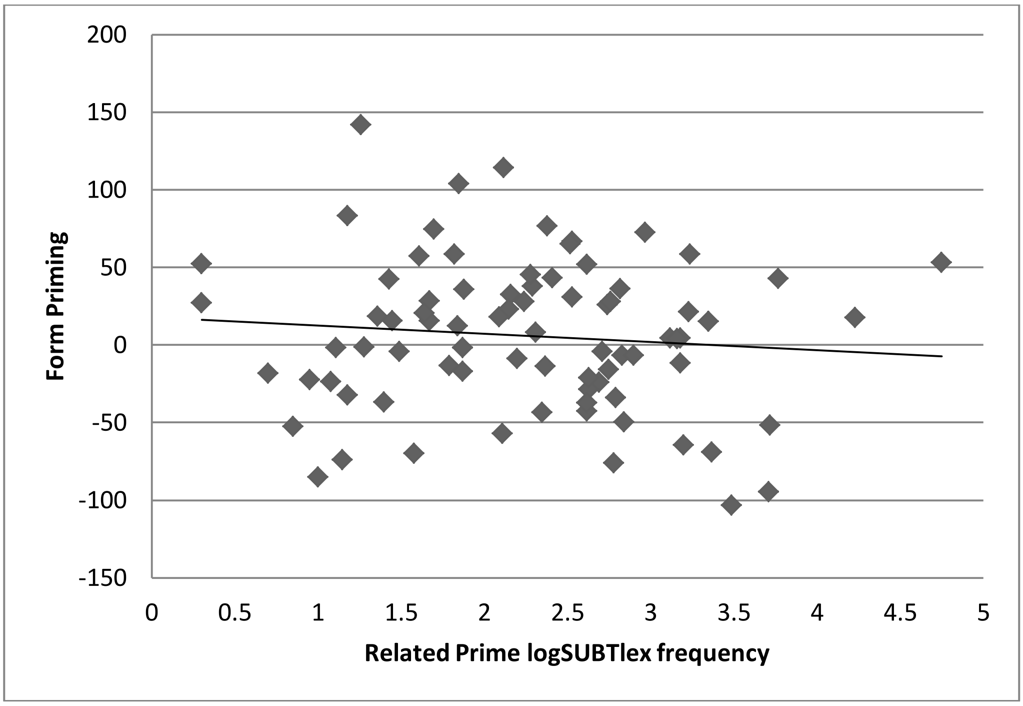


Figure 19. Opaque Condition. Amount of priming (related-control) plotted against LogSUBTlex related prime frequencies.

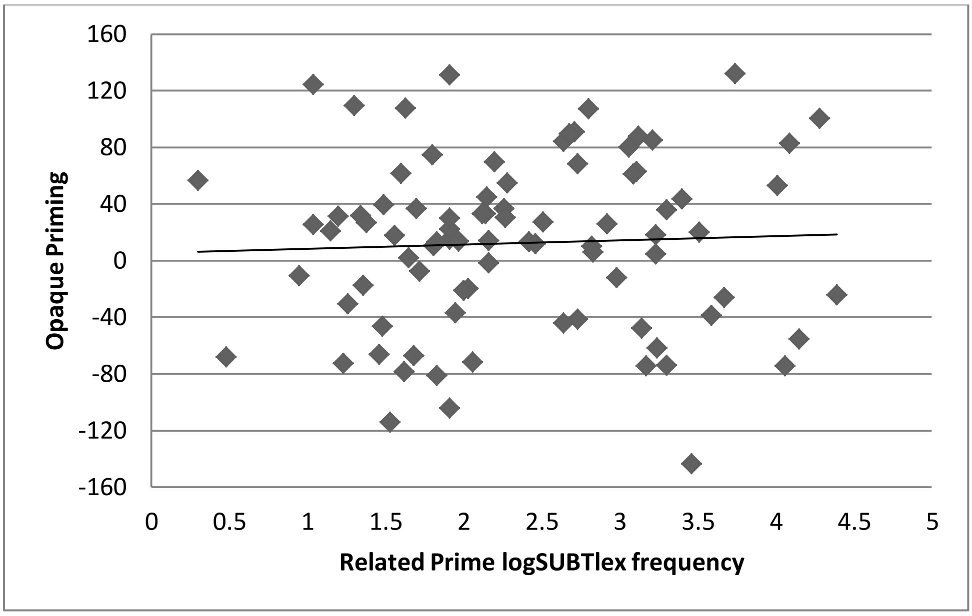
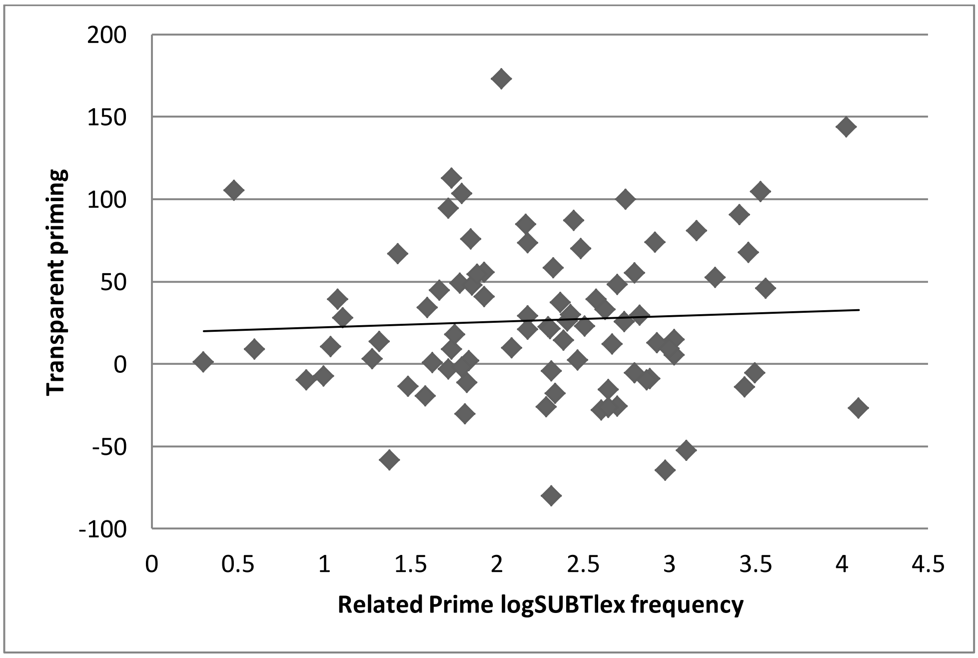


Figure 20. Transparent Condition. Amount of priming (related-control) plotted against LogSUBTlex related prime frequencies.



Error analysis

Error analyses showed a significant effect of condition [F(2,247.9)=8.83, p<0.01], whereby significantly more errors were made in the *form* than in the transparent condition [F(1,167.6)=15.88, p<0.001], and in the opaque compared than in the transparent condition [F(1,165.8)=15.00, p<0.001]. In addition, there was a significant effect of target frequency [F(1,248.3)=55.04, p<0.001], with a negative regression weight of -0.06 [t(248.3)=-7.42, p<0.001], whereby as target frequency increased error rates decreased. Prime frequency did not have an effect on error rates.

8.2.2.2.2. A mixed effects analysis of the non-word prime RTs.

A second mixed effects analysis addressed the question whether the interaction between condition and prime relatedness observed for word primes persists for non-word primes as well. Conditions for this analysis were form and transparent only (see Methods section). Fixed and random effects were entered as outlined above. Due to the nature of the prime only target frequency was entered as a covariate. Results revealed a significant effect of prime relatedness [F(1,4484)=30.88, p<0.001]. There was no significant effect of condition [F(1,76)<1, n.s.], and no interaction between the fixed effects [F(1,4484)=1.91, n.s.], indicating that the amount priming for non-words did not vary as a function of condition. In addition, the analyses showed a significant effect of the covariate target frequency [regression weight of -69.24; t(77)=-6.93, p<0.001], demonstrating that as target frequency increased, reaction latencies decreased.

Error Analysis

Error analysis for non-word primes showed a significant effect of prime relatedness [F(1,4659)=4.14, $p<0.05$]; more errors were made for targets preceded by unrelated compared to related primes. In addition, there was a significant effect of the covariate target frequency [F(1,77)=13.70, $p<0.001$], with a significant regression weight of -0.04 [t(77)=-3.70, $p<0.001$]; thus, as target frequency increased, error rates decreased.

8.3 Discussion

Experiment 5 set out to explore the effects of prime frequency in English native speakers for form, opaque, and transparent prime-target pairs. To this end, the widest possible range of prime frequencies was used, ranging from non-word primes to low-frequency, medium-frequency and high-frequency primes. From previous findings (McCormick et al., 2009) it was not anticipated to find a difference in transparent morphological priming as a function of prime frequency. However, it was of particular interest whether the priming effect would decrease as a function of prime frequency for the opaque and form primes, in line with the orthographic inhibition effect that has been reported for high-frequency primes and orthographically related, lower frequency targets (see Introduction). Experiment 5 replicated McCormick et al. (2009) in finding no effect of prime frequency on the amount of priming for the transparent condition, with comparable priming magnitudes across all frequencies. In addition, results demonstrated that the frequency of the prime did not significantly affect the amount of priming for the opaque condition, again demonstrating comparable priming magnitudes across all frequencies, although overall these were numerically smaller than in the transparent condition. For the form condition, only primes of similar frequency to the targets produced priming (29ms). Primes lower in frequency than their respective targets resulted in negligible priming (2ms), whereas primes higher in frequency than their respective targets resulted in inhibitory priming (-15ms). However, overall, the findings of Experiment 5 indicate that prime frequency is unlikely to be the reason for the findings obtained in English in Experiments 1 and 2. Although there is a tendency towards inhibition for form primes, this is only true for very high frequency primes (as demonstrated by Segui & Grainger, 1990). In fact, with regards to overall differences between conditions, Experiment 5 presents further evidence that in English native speakers, transparent priming (25ms) is robustly greater than form priming (6ms) and overall tends to be larger than opaque priming (13ms). At the same time, opaque priming is larger than form priming. These findings are in line with the conclusions drawn by Rastle and Davis (2008) on the basis of a literature review. However, the results obtained in Experiment 5 differ from results obtained with bilingual English L1 speakers in Experiment 1. Experiment 5 established that for English native speakers, prime frequency does not appear to significantly influence morphological processing. One possible reason as to why priming patterns differed between participants in Experiments 1, 2, and 5 may be related to the knowledge of more than one language. In order to explore the issues of prime frequency in relation to bilingual morphological processing, the stimuli of the present experiment were tested with English L2 speakers in Experiment 6 (Chapter 9).

Chapter 9

Frequency Effects on Morphological Processing in English L2 Speakers

9.1 Introduction

The findings of Experiment 5 demonstrated that for English native speakers, manipulating the relative frequency between primes and targets did not result in significant differences in the overall priming patterns between the form, opaque and transparent condition. Indeed, prime frequency did not appear to be able to provide an explanation as to why bilingual native English speakers demonstrated form priming patterns comparable to the magnitudes obtained with opaque and transparent items in Experiment 1. In fact, Experiment 5 showed that when the variable of prime frequency is not taken into account, overall priming patterns for form, opaque, and transparent items were comparable to those reported in the literature (see Rastle & Davis, 2008), rather than those of Experiment 1.

In relation to bilingual word processing, as also pointed out in Chapter 5, the few studies into bilingual morphological processing conducted thus far have produced contradictory results. Within the bilingual literature, only a handful of studies to date have examined the effects of frequency in relation to morphological processing. However, there are no studies that have examined prime frequency effects in relation to the 'form-then-meaning' debate. With respect to frequency effects, Lehtonen and Laine (2003) for example, found that Finnish L2 (with Swedish as L1) speakers process low, medium, and high frequency inflected Finnish nouns slower than low, medium and high frequency monomorphemic nouns. On the other hand, Finnish L1 speakers only process low frequency inflected nouns slower than low frequency monomorphemic words. According to the authors, this indicates that Finnish-Swedish bilingual speakers decompose inflected nouns at all frequencies, whereas Finnish native speakers only decompose low frequency inflected nouns. Swedish L2 (with Finnish as L1) speakers on the other hand showed similar morphological processes compared to Swedish L1 speakers, with morphological decomposition for low frequency but not for medium and high frequency inflected Swedish nouns (Lehtonen, Niska, Wande, Niemi, & Laine, 2006). Recently, Clahsen and Neubauer (2010) demonstrated that compared to native speakers, German L2 speakers (with Polish as L1) showed larger frequency surface effects for morphologically complex German words ending in the suffix *–ung*. Specifically, German L2 speakers had longer reaction latencies to low frequency than high frequency surface nouns (Experiment 1). However, in relation to morphological processing, German L2 speakers showed no priming effect with morphologically complex primes (e.g., *Zündung –zünden*; *ignition-ignite*) contrasting the large priming effects (71ms) obtained with German native speakers (Experiment 2).

Given that the results of Experiment 5 indicated that prime frequency does not appear to account for the priming patterns obtained with native English speakers in Experiment 1 (particularly the large form priming effect), Experiment 6 was carried out with highly proficient German (L1) – English (L2) participants in order to study the role of prime frequency in bilingual morphological processing. In addition, Experiment 6 was conducted to examine whether prime frequency may account for the priming pattern obtained with German (L1) – English (L2) bilinguals in Experiment 2, which demonstrated large priming effects across the form, opaque and transparent condition.

9.2 Experiment 6 – English L2

9.2.1 Method

9.2.1.1 Stimuli and Apparatus

Stimuli and apparatus were identical to those described for Experiment 5.

9.2.1.2 Participants

Participants were 54 German native speakers who were recruited at Royal Holloway, University of London. Participants were both students and staff and all participants were educated at degree level. All participants stated German to be their native language (confirmed at initial contact), and all participants were residing in the United Kingdom at the time of the experiment, either for educational or work related purposes. The experimenter spoke English with all participants throughout the experiment to ascertain whether the participants were indeed fluent in English. All participants were fluent speakers of English, and demonstrated no difficulties in their command of the English language. All participants had normal or corrected-to-normal vision and no known diagnosis of a reading disorder. The experiment took between 90 to 100 minutes, and participants were paid £15 in exchange for their time.

9.2.1.3 Procedure

The procedure for the online lexical decision task was identical to that of Experiment 5. However, in addition to the lexical decision task, all participants were asked to complete the revised version of the Gradient Bilingual Dominance Scale as well as the Translation task (see Chapter 11). Also, at the very end of the experiment, participants were presented with a ‘pen and paper’ lexical decision task (see Appendix 10) whereby a list of all primes presented during the online lexical decision task was shown on paper. Participants were asked to place a tick in the ‘yes’ column if the word was a real English word, or conversely tick the ‘no’ column if they did not believe the word to exist in English.

9.2.2 Results

Reaction times (RTs) were collected for all participants. Incorrect responses (10.8%) were removed from the analyses, and data below 100ms and above 2000ms (0.8% of data) were discarded. Items that incurred more than 50% errors (8 form, 6 opaque, 1 transparent item[14]) were removed from the analysis. Results are presented in Table 25. Analyses were performed as described in Chapter 8, including the covariates of prime and target length, letter overlap, and prime-target letter difference for the ANCOVA analyses.

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[14] Deleted items were: form: untold-UNTO, flank-FLAN, gallop-GALL, wrench-WREN, branch-BRAN, charge-CHAR, produce-PROD, though-THOU; opaque: basalt-BASAL, crater-CRATE, battle-BATT, matter-MATT, routine-ROUT, section-SECT; transparent: curdle-CURD

Table 25. Experiment 6. English as L2 for German L1 – English L2 bilinguals. Reaction times (in milliseconds), priming effects (in ms) and standard deviations (in ms) for condition by frequency by prime.

Condition	Frequency and prime	Mean	Priming	Std. Deviation
Form	*Low related*	740	*5*	232
	Low control	745		210
	Medium related	763	*22*	243
	Medium control	785		248
	High related	791	*29*	253
	High control	820		292
Opaque	*Low related*	749	*14*	240
	Low control	763		245
	Medium related	745	*47*	224
	Medium control	792		262
	High related	783	*-4*	262
	High control	779		247
Transparent	*Low related*	725	*38*	237
	Low control	763		255
	Medium related	726	*20*	232
	Medium control	746		215
	High related	738	*29*	236
	High control	767		250

9.2.2.1 ANCOVA for word prime RTs

Results demonstrated a significant main effect of condition [$F_1(2,104)=17.87$, $p<0.001$; $F_2(2,234)=7.85$, $p<0.001$]. Bonferroni post-hoc tests showed that transparent and opaque items were responded to faster than form items (all $ps<0.05$). In addition, planned comparisons showed that transparent items were also responded to faster than opaque items [$t_1(53)=4.67$, $p<0.001$; $t_2(171)=2.378$, $p<0.05$].

Results further demonstrated a significant main effect of frequency [$F_1(2,104)=32.19$, $p<0.001$; $F_2(2,234)=3.05$, $p=0.049$]. Planned comparisons showed that as prime frequency increased, so did reaction latencies (see Table 26 for reaction times collapsed over condition and relatedness). Thus, overall, targets preceded by low frequency primes were responded to faster than when preceded by medium (significant over participants only) [$t_1(53)=-2.88$, $p<0.05$; $t_2(171)=-1.11$, n.s.] and high [$t_1(53)=-6.42$, $p<0.001$; $t_2(167)=-2.57$, $p<0.05$] frequency primes. Targets preceded by medium frequency primes were also responded to faster than when preceded by high frequency primes [$t_1(53)=-6.42$, $p<0.001$; $t_2(167)=-2.57$, $p<0.05$].

Table 26. Reaction Times (in milliseconds) for Experiment 6 (English as L2 for German L1 – English L2 bilinguals) collapsed over condition and relatedness.

Frequency	Mean	Std. Deviation
Low	747	237
Medium	758	238
High	777	257

There was a also a significant effect of prime over participants only [$F_1(1,52)=23.09$, $p<0.0001$; $F_2(1,234)<1$, n.s.], showing the targets preceded by related primes were responded to faster than targets preceded by control primes (see Table 27 for reaction times collapsed over frequency). It should be noted here, however, that when the analysis is performed without the covariates, the effect of prime is also highly significant over items [$F_2(1,237)=24.36$, $p<0.0001$].

Table 27. Experiment 6. English as L2 for German L1 – English L2 bilinguals. Reaction times (in milliseconds) collapsed over frequency. Standard deviations (in ms), and percentage of errors.

		Condition								
		<u>Form</u>			<u>Opaque</u>			<u>Transparent</u>		
	Prime	*M*	*SD*	*% error*	*M*	*SD*	*% error*	*M*	*SD*	*% error*
Non-Word	Related	732	224	10.5				733	224	8.5
	Control	766	225	12.3				769	234	9.6
	<u>Priming effect</u>	*34*		*1.8*				*36*		*1.1*
Word Primes	Related	763	243	11.9	758	242	15.2	730	235	5.6
	Control	781	251	13.4	778	252	14.5	759	240	5.7
	<u>Priming effect</u>	*18*		*1.5*	*20*		*-0.7*	*29*		*0.1*

The interaction between condition and frequency was significant over participants [$F_1(4,208)=5.47$, $p<0.001$; $F_2(4,234)=1.54$, n.s.]. As can be seen in Table 28, as frequencies increased, so did reaction times across conditions, with the exception of the transparent condition, whereby medium frequencies drew slightly shorter reaction latencies than low frequency items. There was no significant interaction between condition and prime [$F_1(2,104)<1$ n.s.; $F_2(2,234)<1$, n.s.], indicating the priming magnitude did not vary across the form, opaque, and transparent condition (18ms, 20ms, and 29ms, respectively). There was no significant interaction between frequency and prime [$F_1(2,104=1.29$, n.s.; $F_2(2,234)<1$ n.s.], indicating that across the low, medium, and high frequency conditions, the magnitude of priming was comparable (24, 31, and 22ms, respectively). There was a just significant three-way interaction between condition, frequency and prime over participants only [$F_1(4,208)=2.46$, $p=0.046$; $F_2(4,234)=1.85$, n.s.]. As can be seen in Table 25, in the transparent condition, there was a larger priming magnitude across all frequencies

(38, 20, and 29ms). However, in the form condition, there was only minimal priming for low frequencies items (5ms), whereas both medium and high frequency items showed larger priming effects (22 and 29ms, respectively). This trend, however, was reverse for opaque items, with the largest overall priming effect for medium frequency items (47ms) and slight inhibition for high frequency items (-4ms).

None of the covariates reached significance (all ps>0.05) or interacted with any of the main effects (all Fs<1).

Table 28. Experiment 6 – English as L2 – for German L1 – English L2 bilinguals. Means and standard deviation (in milliseconds) collapsed over relatedness.

Frequency	Condition	Mean	Std. Deviation
Low	*Form*	742	221
	Opaque	756	243
	Transparent	744	247
Medium	*Form*	774	245
	Opaque	769	245
	Transparent	736	224
High	*Form*	805	273
	Opaque	781	255
	Transparent	752	244

Errors Analyses

Error analyses revealed a significant main effect of condition [$F_1(2,104)=80.89$, $p<0.001$; $F_2(2,234)=13.04$, $p<0.001$], with Bonferroni post-hoc tests demonstrating that more errors were made to form and opaque items than to transparent items (all ps<0.01). Planned contrast (significant over participants only) also showed that more errors were made to opaque than to form items [$t_1(53)=-3.41$, $p<0.01$;

$t_2(164)=-1.07$, n.s]. There was also a significant main effect of frequency [$F_1(2,104)=40.43$, $p<0.001$; $F_2(2,234)=4.08$, $p<0.05$], showing that as frequency increased, so did error rates. Thus, more errors were made to targets preceded by high frequency primes compared to both medium [$t_1(53)=-6.06$, $p<0.001$; $t_2(166)=-1.97$, $p=0.05$] and low frequency primes [$t_1(53)=-7.71$, $p<0.001$; $t_2(167)=-2.74$, $p<0.01$]. Also, more errors were made to items preceded by medium frequency primes compared to low frequency primes [$t_1(53)=-2.01$, $p=0.05$; $t_2(171)=-0.68$, n.s.]. Further, there was a significant interaction between condition and frequency over participants [$F_1(4,208)=10.84$, $p<0.001$; $F_2(4,234)=1.44$, n.s.], showing that for both form and opaque condition, error rates increased with increasing frequency, whereas for the transparent condition, error rates did not change as a function of frequency.

The main effect of prime was not significant (all Fs<1), neither was the interaction between prime and frequency (all Fs<1), or condition and prime (all ps>0.05). The three-way interaction between condition, frequency and prime was also non-significant (all ps>0.05). None of the covariates reached significance (all ps>0.05) or interacted with any of the main effects (all Fs<1), indicating that the differences in letter length between and across conditions did not affect error rates significantly.

9.2.2.2 ANOVA for non-word type prime RTs

Analyses revealed a significant main effect of prime only [$F_1(1,52)=27.421$, $p<0.001$; $F_2(1,76)=23.761$, $p<0.001$], demonstrating that targets preceded by related primes were responded to significantly faster than targets preceded by control primes (see also Table 27, p. 199). There was no significant effect of condition (all Fs<1) and no significant interaction between the main effects (all Fs<1).

Error Analyses

Error analyses showed a significant main effect of condition over participants [$F_1(1,52)=7.87$, $p<0.01$; $F_2(1,76)<1$], demonstrating that more errors were made to targets preceded by form-type non-word primes compared to transparent-type non-word primes. There was also a significant main effect of prime over participants [$F_1(1,52)=5.07$, $p<0.01$; $F_2(1,76)=3.30$, $p>0.05$], with targets preceded by control primes drawing more errors compared to targets preceded by related primes. There was no interaction between the main effects (all Fs<1).

9.2.3 Mixed Model Analyses

A mixed model analysis was performed as described in Chapter 8.

Analyses revealed a significant main effect of condition [$F(2,240)=4.71$, $p<0.05$]. Further analyses showed this difference to be significant between the form and transparent condition, indication that form items were responded to slower than transparent items [$F(1,161)=7.74$, $p<0.01$]; and between the opaque and transparent items [$F(1,164)=5.87$, $p<0.05$], indicating that opaque items were responded to slower than transparent items. Mixed model analyses further revealed a significant main effect of prime [F(1,11536)=43.45, p<0.001], demonstrating that targets preceded by related primes were responded to faster than targets preceded by control primes. The interaction between the two main effects was not significant (F<1). The was a clear effect of the continuous variable of target frequency [regression weight of -76.3; t(241)=-8.92, p<0.001], indicating that as target frequency increased, reaction latencies decreased. The continuous variable of prime frequency was not significant, [regression weight of +6.8; t(1.7), p=0.085]. In addition, there was no significant interaction between the continuous (prime and target frequency) and discrete (condition and prime) effects (all Fs<1). The lack of a significant interaction between prime frequency and the priming effect is shown in Figures 21-23, where for the three different conditions (form, opaque, transparent) the priming effect is plotted as a function of the prime frequency.

Figure 21. Form Condition. Amount of priming (related-control) plotted against LogSUBTlex related prime frequencies. Figure 21 demonstrates that overall, form priming does not vary as a function of prime frequency to a large extent. There is a tendency towards more priming for medium and high frequency items compared to low frequency items, as demonstrated in Table 25.

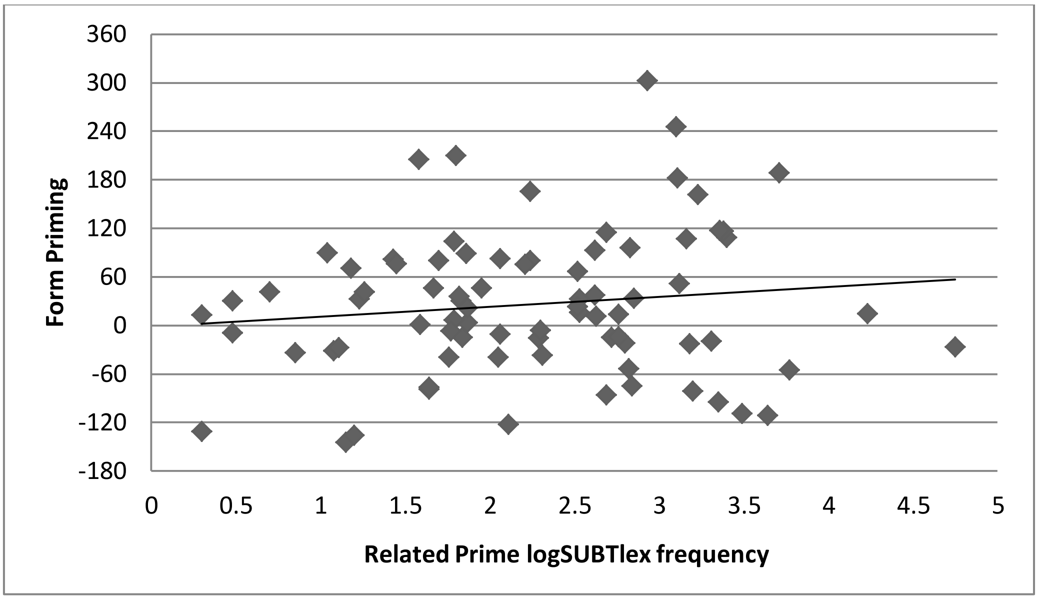


Figure 22. Opaque Condition. Amount of priming (related-control) plotted against LogSUBTlex related prime frequencies. Figure 22 demonstrates that overall, opaque priming does not vary as a function of prime frequency. There is a trend toward less priming for low frequency items (see also Table 25).

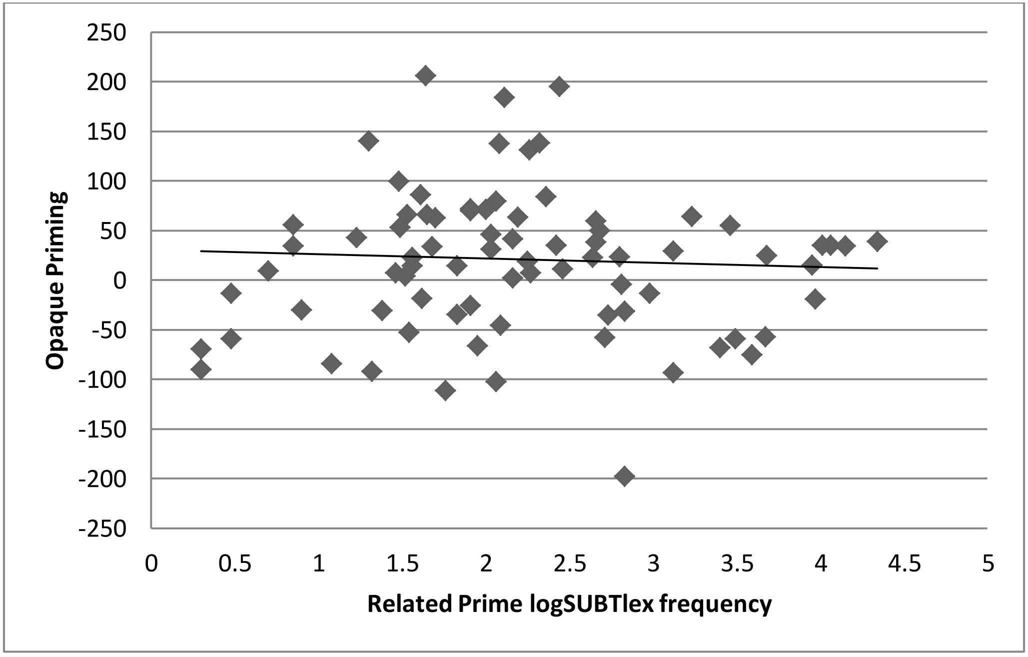
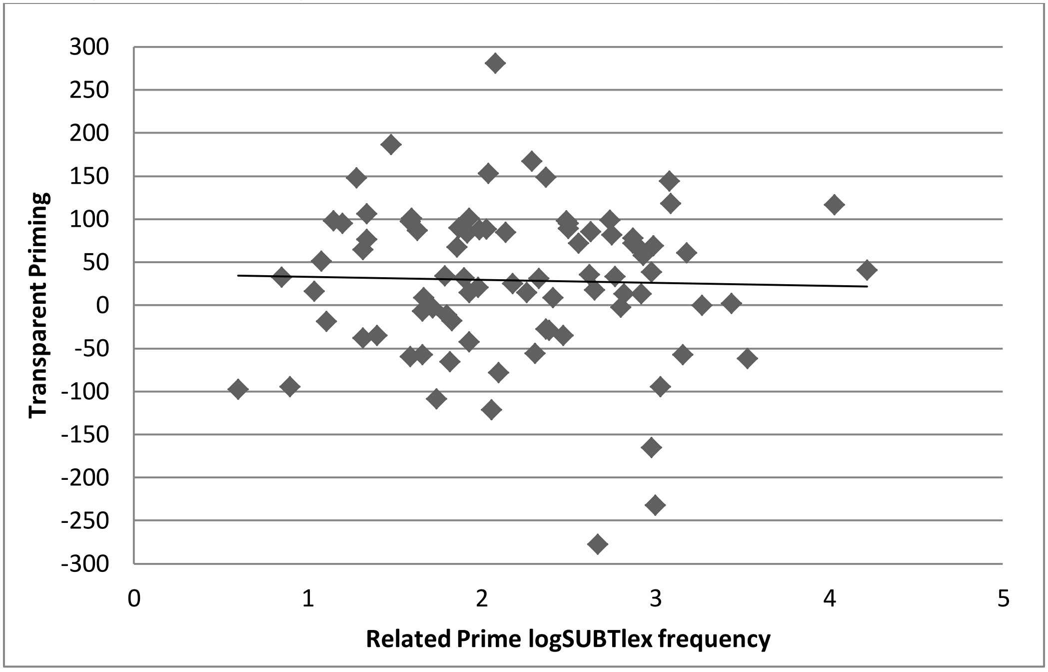


Figure 23. Transparent Condition. Amount of priming (related-control) plotted against LogSUBTlex related prime frequencies. Figure 23 demonstrates that for transparent items, the magnitude of priming does not vary as a function of frequency.



Error Analyses

Error analyses revealed a significant main effect of condition [F(2,239)=16.018, p<0.001], demonstrating that compared to the transparent condition, more errors were made in the form [F(1,161)=18.126, p<0.001] and opaque [F(1,164)=34.897, p<0.001] condition. There was no significant effect of prime on errors, and no significant interaction between main effects (all ps<0.05). There was a significant effect of the continuous variable of target frequency [regression weight of -1; t(240)=-7.982, p<0.001], indicating that more errors were made to targets of lower frequencies. Target frequency did not interact with any of the main effects [all Fs<1].

9.2.3.1 Mixed Model for Non-Word Type Primes

The mixed model analysis of reaction latencies to non-word type primes revealed a significant main effect of prime only [F(1,3728)=33.724, p<0.001], demonstrating that targets preceded by related primes were responded to faster than targets preceded by control primes (see also Table 27, see p. 199). There was no effect of condition (F<1), indicating that reaction latencies did not differ between targets preceded by form-type non-words and transparent-type non-words. There was no interaction between the main effects (F<1). There was significant effect of the continuous variable of target frequency [regression weight of -87.5; t(77)=-7.688, p<0.001], demonstrating that as target frequency increased, reaction latencies decreased. The continuous variable of target frequency interacted with the discrete variable of condition [regression weight of -54.7; t(76)=-24.82; p<0.05], demonstrating that in particular in the form-type non-word prime condition, reaction times decreased as target frequencies increased.

Error Analysis

The main factors of condition and prime were both non-significant (p>0.05), indicating that the number of response errors made did not vary as a function of condition or prime. However, there was a just significant effect of the continuous variable target frequency [regression weight of -0.06; t(76)=-2.079, p=0.041], indicating that there was a trend towards more errors to targets of lower frequency.

9.2.4 Pen and Paper Lexical Decision Task

The paper and pen lexical decision task (see Appendix 10) presented participants with the primes of the form, opaque, transparent, and the two non-word prime conditions. Results are shown in Tables 29 and 30.

Table 29. Percentage (%) of word primes incorrectly judged as non-words.

	Low frequency prime	**Medium frequency prime**	**High frequency prime**
Form	35	9	1
Opaque	32	10	1
Transparent	28	5	1

Table 30. Percentage (%) of non-word primes incorrectly judged as words.

	Percentage incorrectly judged as words
Non-word prime of form type (non-suffix endings)	8
Non-word prime of transparent type (suffix endings)	21

As can be seen in Table 29, for word primes, across all conditions, low frequency word primes condition were most likely to be incorrectly identified as non-words, whereas high frequency primes were most likely to be correctly identified as real English words. For non-word primes, primes ending in a suffix were more likely to be incorrectly identified as a real English word compared to non-words ending in a non-suffix type ending.

9.3 Discussion

Experiment 6 set out to explore the effects of prime frequency on morphological processing in English L2 bilingual speakers. No study to date has used such a wide range of prime frequencies to explore the effects of prime frequency in bilingual morphological word processing. For English native speakers (Experiment 5) it was demonstrated that prime frequency did not significantly affect priming magnitudes in any of three conditions. For English L2 speakers, a similar picture emerged. As Figures 21 to 23 demonstrate, in the opaque and transparent condition, the magnitude of priming did not vary as a function of prime frequency, with the exception of a trend towards less priming for high frequency primes in the opaque condition. For the form condition, there was a moderate trend towards an increase in priming magnitude with increasing frequency. Overall, however, it cannot be said that prime frequency affected priming magnitudes across the conditions. This was also demonstrated by the absence of a significant interaction between condition and prime in the ANCOVA analysis. In fact, disregarding the variable of prime frequency, the results of Experiment 6 are directly comparable with the results of Experiment 2. The bilingual speakers in the present experiment showed large priming effects across the form, opaque and transparent condition (18ms, 20ms, and 29ms, respectively), comparable to the priming magnitudes obtained in Experiment 2 (33ms, 17ms, and 33ms, respectively). As it has been demonstrated in the present experiment that prime frequency cannot account for the pattern of priming, particularly the large form priming, observed in English L2 speakers with German as L1, other explanations must be sought. Two lines of argument appear plausible at this stage. Firstly, Experiment 6 crucially demonstrated that English L2 speakers, in line with English L1 speakers, show large non-word priming effects for both form-type and transparent-type non-words (34ms and 36ms, respectively). Large priming effects with non-words of the form and transparent type have also been reported elsewhere (e.g., Davis, 2010; Longtin et al., 2003; McCormick et al., 2009). If non-word primes cause large priming effects in English L2 speakers, then one possible explanation for the large form priming effects obtained is that many primes in the form condition were treated as non-words. Interestingly, the paper and pen lexical decision task demonstrated that participants made most misattribution errors to form primes, particularly those of low frequency. However, this explanation becomes less plausible in the light of the priming magnitude obtained for low frequency form primes, which was 5ms. Thus, even though low frequency primes were most likely to be regarded as non-words, they did not results in priming magnitude comparable to that of form-type non-words (34ms). Considering that only 1% of high frequency form primes were wrongly judged to be non-words, and given the large degree of priming for this frequency (29ms), another explanation is warranted. The second explanation is that of the participants' bilingual status itself. The participants that took part in Experiments 1-4, as well as 6, were bilingual speakers of English and German, two morphological languages that form derivations, inflections, as well as new words, through affixation. As such, because of their bilingual status, the participants knew many more morphological word endings than contained within their own L1. In other words, a proficient bilingual German and English speaker knows all common English as well as German morphological word endings. It is thus possible that the bilingual status of the participants is driving the large amount of form priming observed in

Experiment 1, 2, and 6. It has already been described in the literature that knowledge of a second language influences word processing in the bilingual’s native language (Van Assche, Duyck, Hartsuiker, & Diependaele, 2009). Thus, Experiment 7 explores whether knowledge of a second language influences visual word processing in L1 to such an extent that morphological decomposition strategies are applied to all words of an apparent stem + word-like suffix structure.

Chapter 10

The Effects of Second Language Knowledge on Morphological Processing in L1

10.1 Introduction

The findings of Experiment 6 demonstrated that in speakers of English as L2, the processing of morphologically complex words does not appear to be influenced by prime frequency. In addition, the results obtained with English L2 speakers in Experiment 2, demonstrating large priming effects across the form, opaque, and transparent condition, were replicated in a larger sample of English L2 speakers in Experiment 6.

Contrary to initial assumptions and as demonstrated in Experiment 5, the role of prime frequency was also not able to account for the large degree of form priming obtained with bilingual English L1 speakers in Experiment 1. As outlined in Chapter 9, the possibility that knowledge of a second language influences native language processing strategies is intriguing. Only a few studies within psycholinguistics have been conducted with respect to how L2 impacts on L1 processing. For example, Van Hell and Dijkstra (2002) observed facilitation effects with cognates in Dutch L1 trilingual speakers, with English and French as additional languages. Specifically, participants responded faster to Dutch-English and Dutch-French cognates than to non-cognate words. On the other hand, Ivanova and Costa (2008) demonstrated that bilingual speakers incurred processing costs during picture naming in their first and dominant language. Compared to monolingual speakers, Spanish-Catalan and

Catalan-Spanish bilinguals were slower in naming pictures in their respective L1s. Interesting, and in contrast to Van Hell and Dijkstra (2002), naming was slower for both cognates and non-cognates.

In order to ascertain whether knowledge of a second language (in this case German) impacts on the way English native speakers process words of an apparent stem+word-like suffix structure, a replication of Experiment 1 with a group of monolingual speakers of English was conducted. It was of particular importance that none of the participants in Experiment 7 were able to speak any language other than English.

10.2 Experiment 7: English Monolinguals

10.2.1 Methods

The stimuli for Experiment 7 were identical to those of Experiment 1.

10.2.1.1 Procedure

The procedure was identical to that of Experiment 1.

10.2.1.2 Participants

Participants were recruited on campus. The experiment was advertised with the constraint that participants had to be monolingual speakers of English, and thus should not be able to hold a conversation in any language other than English. Forty-one participants took part in the experiment. On arrival, each participant was asked about their knowledge of foreign languages. Questions included whether they were able to read and comprehend a written text in another language, or hold a conversation in any language other than English. Although all participants would have had compulsory foreign language tuition at secondary school, all but one participant regarded their knowledge of another foreign language as insufficient to even hold a short conversation. One participant had to be excluded from the analysis due to reasonable knowledge of the Spanish language. Thus, all remaining participants were classed as monolingual speakers of English. The experiment took approximately 20 minutes and participants were offered £5 in exchange for their time.

10.2.2 Results

Results were analyses as described in Experiment 1. Incorrect responses (234 data points) were excluded. Reaction time data were cleaned and only RTs between 100ms and 2000ms were included in the analysis, resulting in the removal of a further 2 data points. No items were deleted as all received a correct response from more than half the participants. Mean RTs and SDs are presented in Table 31.

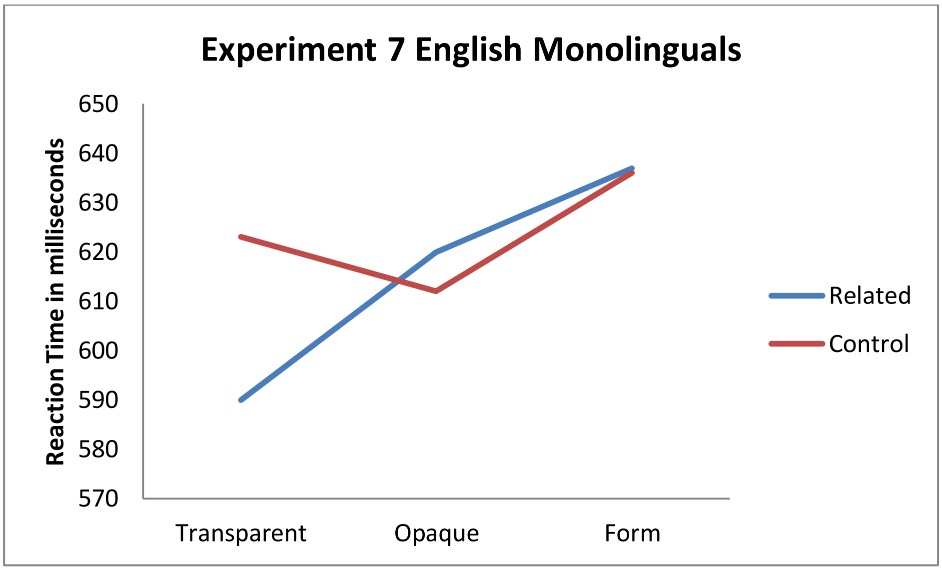
Table 31. Experiment 7. English – English monolingual speakers. Mean Reaction Time (RT) in milliseconds, Standard Deviation (SD) and Priming Magnitude per Condition.

	Transparent (SD)	*% Error*	*Opaque (SD)*	*% Error*	*Form (SD)*	*% Error*
Related prime	590 (154)	2.5	620 (178)	6.6	637 (176)	7.2
Control prime	623 (158)	6	612 (141)	8.2	636 (175)	8.5
Priming effect	*33*	*3.5*	*-8*	*1.6*	*-1*	*1.3*

Analyses revealed a significant main effect of condition over participants [$F_1(2,76)=14.467$, $p<0.001$; $F_2(2,84)=1.968$, n.s.]. Although Bonferroni corrected post-hoc tests did not indicate a significant difference between conditions, planned comparisons showed this difference to be between the form and opaque condition (significant over participants only) [$t_1(39)=3.625$, $p<0.01$; $t_2(58)=1.099$, n.s.], demonstrating that opaque items were responded to faster than form items; and between the form and transparent condition [$t_1(39)=4.4793$, $p<0.01$; $t_2(58)=2.052$, $p<0.05$], showing that transparent items were responded to faster than form items.

Further, analyses showed a significant main effect of prime, [$F_1(1,38)=4.416$, $p<0.05$; $F_2(1,84)=4.131$, $p<0.05$], demonstrating that overall, targets preceded by related primes were responded to faster than targets preceded by control primes. In addition, there was a significant interaction between condition and prime [$F_1(2,76)=8.833$, $p<0.001$; $F_2(2,84)=5.123$, $p<0.01$]. As can be seen in Figure 24, targets preceded by related primes were responded to faster in the transparent compared to the form and opaque condition, resulting in a large priming effect for the transparent condition. The magnitude of priming was further analysed as a dependent variable by means of planned comparisons [$F_1(2,78)=8.884$, $p<0.001$; $F_2(2,78)=5.164$, $p<0.01$], demonstrating that there was significantly more priming in the transparent condition compared to both the opaque [$t_1(39)=-3.607$, $p<0.01$; $t_2(58)=-2.986$, $p<0.01$] and the form condition [$t_1(39)=-3.843$, $p<0.001$; $t_2(58)=-2.235$, $p<0.05$].

Figure 24. Reaction times in ms for English monolinguals for related and control primes, across form, opaque and transparent conditions.



Error Analyses

Error analyses revealed a significant main effect of condition over participants [$F_1(2,76)=7.767$, $p<0.01$; $F_2(2,84)=1.130$, n.s.]. Bonferroni post-hoc test showed no difference in the number of errors between conditions; planned comparisons (significant over participants only) showed that more errors were made to form items compared to transparent items [$t_1(29)=3.480$, $p<0.01$; $t_2(58)=1.563$, n.s.]; more errors were also made to opaque compared to transparent items [$t_1(39)=4.050$, $p<0.05$; $t_2(58)=1.272$, n.s.]. Further, there was a significant main effect of prime [$F_1(1,38)=6.132$, $p<0.05$; $F_2(1,84)=4.741$, $p<0.05$] demonstrating that more errors were made to targets preceded by control primes compared to targets preceded by related primes. No other effects were significant.

10.2.3. Comparison between English L1 Monolingual and Bilingual Speakers

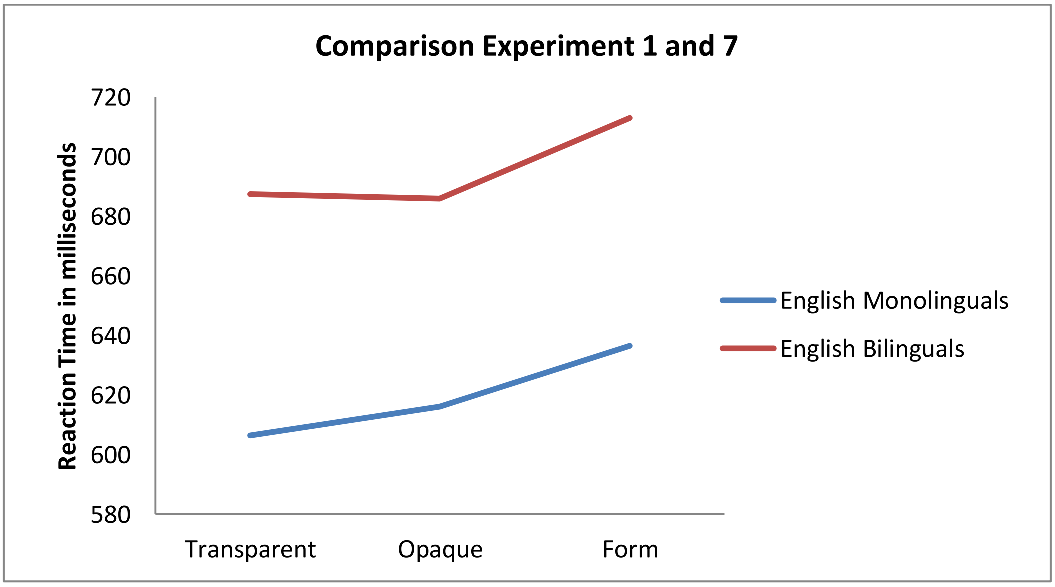
A cross-language comparison was conducted between English L1 monolingual speakers (Experiment 7) and English L1 bilingual speakers (Experiment 1), using ANOVA as well as mixed model analyses.

10.2.3.1 ANOVA Analyses Comparing Experiment 1 and 7

The ANOVA analysis revealed a significant main effect of condition over participants only [$F_1(2,124)=18.072$, $p<0.001$; $F_2(2,84)=1.942$, n.s]. Although Bonferroni post-hoc analyses did not show a significant difference between condition, planned comparisons (significant over participants only) demonstrated a significant difference between the form and opaque condition [t1(40)=4.169, $p<0.001$; t2(58)=1.299, n.s], with form items being responded to slower than opaque items; and between the form and transparent condition [$t_1(40)=4.608$, $p<0.05$; $t_2(58)=1.974$, $p=0.053$], with transparent items being responded to faster than form items.

In addition, there was a significant main effect of prime, [$F_1(1,62)=26.946$, $p<0.001$; $F_2(2,84)=14.623$, $p<0.001$], indicating that targets preceded by related primes were responded to faster than targets preceded by control primes. Further, there was a significant interaction between condition and prime [$F_1(1,124)=6.785$, $p<0.01$; $F_2(2,84)=2.787$, $p=0.067$]. Planned comparisons with priming as dependent variable indicated that the magnitude of priming was significantly larger in the transparent compared to both the opaque [$t_1(40)=-3.703$, $p<0.01$; $t_2(58)=-1.879$, $p=0.065$] and form condition [$t_1(40)=-3.986$, $p<0.001$; $t_2(58)=-2.686$, $p<0.01$]. In addition, there was a significant main effect of language [$F_1(1,62)=7.046$, $p<0.05$; $F_2(1,84)=276.833$, $p<0.0001$], demonstrating that monolingual English speakers made faster overall lexical decisions (M=620) than bilingual English L1 speakers (M=695). Thus, monolingual speakers were, on average, 75ms faster in their decision making compared to bilingual English L1 speakers (see also Figure 25).

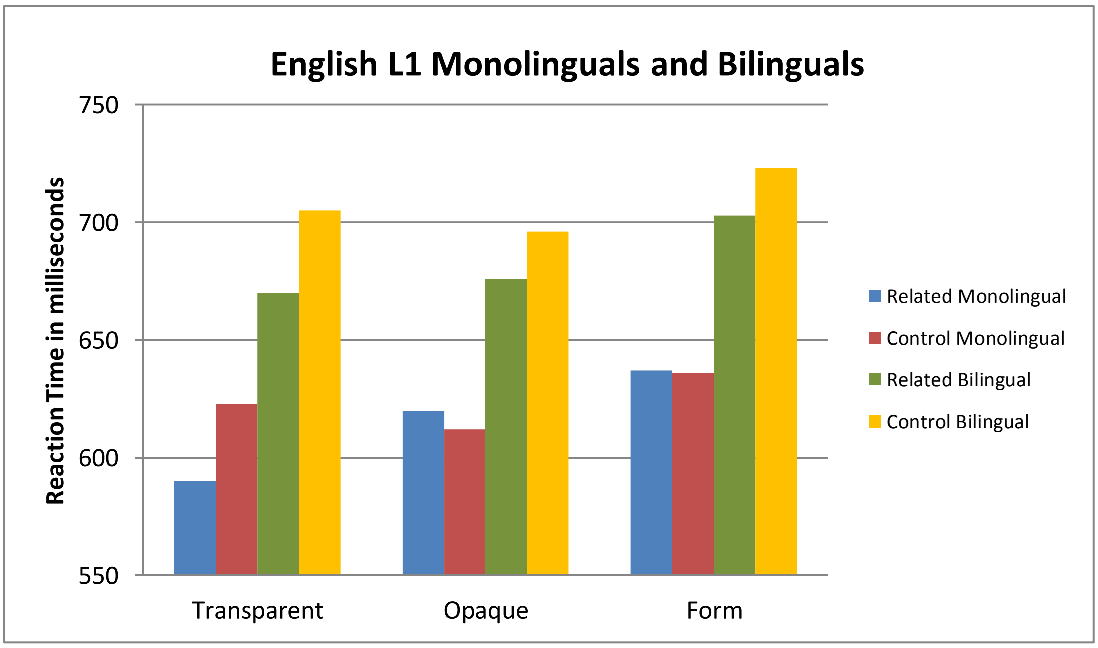
Figure 25. Mean Reaction Times in English for Monolingual and Bilingual English L1 Speakers collapsed over conditions.



Further, there was a significant interaction between prime and language [$F_1(1,62)=6.554$, $p<0.05$; $F_2(1,84)=3.473$, $p=0.06$], with more overall priming for bilinguals (25ms) than monolinguals (9ms). Further, reaction times for targets preceded by related and control primes were shorter for monolinguals (615ms and 624ms, respectively) than bilinguals (683ms and 708ms, respectively).

Although the three-way interaction between condition, prime and language was non-significant (all ps>0.05), Figure 26 clearly shows the difference in priming patterns between the two groups of participants. Specifically, it demonstrates that for English L1 bilinguals, there was a comparable priming magnitude across all three conditions, whereas for English monolinguals, considerable priming was only found in the transparent condition.

Figure 26. Cross-language comparison in English between English L1 monolingual and bilingual speakers for related and control primes, across conditions. Reaction times are stated in milliseconds.



Error Analyses

There was a significant main effect of condition over participants [$F_1(2,124)=12.275$, $p<0.001$; $F_2(2,84)=1.603$, $p>0.05$], demonstrating that more errors were made in the form compared to the transparent condition [$t_1(40)=3.524$, $p<0.01$; $t_2(58)=1.880$, p>0.05]; more errors were also made in the opaque compared to the transparent condition [$t_1(40)4.280$, $p<0.05$; $t_2(58)=1.286$, $p>0.05$]. In addition, analyses revealed that more errors were made to targets preceded by control primes compared to related primes [$F_1(1,62)=7.320$, $p<0.01$; $F_2(1,84)=11.271$, $p<0.01$]. Further, more errors were made by monolingual English L1 speakers than bilingual English L1 speakers [$F_1(1,62)=6.631$, $p<0.05$; $F_2(1,84)=4.822$, $p<0.05$]. No other effects were significant.

10.2.3.2 Mixed Model Analysis Comparing Experiments 1 and 7

A mixed model analysis was performed with DJMIXED in addition to the traditional ANOVA analyses. Results followed a similar trend as the ANOVA analyses, although overall, they were more conservative. Specifically, the mixed model revealed a significant main effect of prime [$F(1,5446)=21.94$, $p<0.001$], demonstrating that overall, targets preceded by related primes were responded to faster than targets preceded by control primes. There was also a significant interaction between prime and condition [$F(2,5446)=5.08$, $p<0.01$], indicating that overall, across both languages, there was more priming in the transparent than the opaque and form condition (see also Figure 26). The effect of language was also significant [$F(1,66)=6.93$, $p<0.05$], demonstrating that monolingual L1 speakers made faster overall decision latencies compared to English L1 bilingual speakers. The interaction between language and prime was also significant [$F(1,5445)=4.08$, $p<0.05$], demonstrating that overall, English L1 bilingual speakers showed more priming that English monolingual speakers. No other effects were significant.

Error Analyses

Error analyses with DJMIXED revealed a significant main effect of prime [F(1,5776)=8.71, p<0.01], demonstrating that more errors were made to targets preceded by control primes than related primes. In addition, a significant effect of language was obtained in the mixed effects error analysis [F(1, 66)=6.68, p<0.05], demonstrating that English L1 monolingual speakers made significantly more errors than English L1 bilinguals speakers.

10.3 Discussion

Experiment 7 set out to explore whether the results obtained with English L1 bilingual speakers in Experiment 1 could be, to some extent, accounted for by the bilingual status of the participants. Using only monolingual speakers of English, the stimuli of Experiment 1 were re-tested in Experiment 7. The results revealed an interesting pattern. English native speakers who speak no language other than their mother tongue only showed significant facilitation for targets preceded by primes that shared both a morphological and semantic relationship with their respective targets. Indeed, primes that were only morphologically but not semantically related caused slight inhibition of target recognition. Primes that were neither morphologically nor semantically related to their respective targets showed a negligible inhibition effect of -1ms. It can thus be argued that the results of Experiment 7 indicate that monolingual speakers of English decompose items that are both morphologically complex and semantically transparent into their respective stems and affixes, whereas apparent morphologically complex but semantically opaque items are processed akin to monomorphemic words. Drawing this conclusion, however, begs the question how the results of Experiment 7 compare to those of Experiment 5 and the many studies reported in the literature demonstrating at least moderate priming for opaque items. One possibility relates to the language status of the participants themselves. Although Experiment 5 used native English speakers as participants, no restrictions were placed upon their language status. In other words, it is possible that the participants in Experiment 5 consisted of a mixture of true monolinguals, as well as bilingual English L1 speakers, and native English speakers with some knowledge of another language. This may have contributed to the moderate opaque priming effect obtained. At present, there are no published studies that compare monolingual English speakers with English L1 bilinguals with respect to morphological processing. However, some studies have compared these two groups on other measures. For example, Ransdell and Fischler (1987) demonstrated that in an exclusively monolingual task, compared to monolingual English speakers, bilingual English L1 speakers were slower to respond to English concrete and abstract words in a lexical decision task, and slower, but not less accurate, in remembering a list of abstract words. Although Ransdell and Fischler (1987) concluded that L2 knowledge seems to have little influence on L1 processing, the cross-language comparison between Experiments 1 and 7 in this work may suggest that there is some influence of L2 on L1. Indeed, the cross language comparison showed that compared to monolinguals, English L1 bilinguals were slower in their response times across all conditions, regardless of the morphological status of the prime. In addition, English L1 bilinguals also showed more priming across all conditions. It would be difficult to attribute these slower response times to cross-language activations, as demonstrated with cognates by Van Assche, Duyck, Hartsuiker, & Diependaele (2009), as during stimuli selection all efforts were made to exclude word that are cognates and homophones with German (see Experiment 1). It is however possible that the knowledge of another, arguably similar but morphologically richer, language affects how both monomorphemic and morphologically complex words are processed in L1. Thus, the findings of Experiment 7 may suggest that in visual word processing, English L1 – German L2 bilingual speakers apply a decomposition process to all words of an apparent word+suffix-like-ending type, irrespective of whether the word ends in a true suffix or a more infrequent but legal word ending. Chapter 12 attempts to place these findings within the wider context of bilingual research and models of bilingual word processing.

Chapter 11

Language Proficiency Assessment

The degree of proficiency at which a bilingual is able to communicate in their L2 may depend on a variety of factors, such as the age of acquisition of L2, the time an individual has spent in their L2's environment, or whether or not L2 was spoken at home (see Dunn & Fox Tree, 2009). However, bilinguals tend to be poor at accurately assessing their own levels of proficiency. In fact, it has been demonstrated that L2 speakers of a more anxious disposition tend to underestimate their L2 proficiency, whereas less anxious bilinguals overestimate their L2 abilities (MacIntyre, Noels, Clement, 1997). It is therefore important to assess bilinguals' L2 proficiency levels using measures that do not rely on self-assessment. Thus, the recently published Gradient Bilingual Dominance Scale (Dunn & Fox Tree, 2009), which does not contain items that require self-ratings, as well as a translation task were used to assess the proficiency of the bilingual speakers who took part in Experiments 1-4 and 6.

11.1 Experiments 1-4

All participants who took part in Experiments 1-4 completed the Gradient Bilingual Dominance Scale (Dunn & Fox Tree, 2009), a paper and pen questionnaire assessing language dominance. Completion of the scale was combined with a translation task to assess proficiency (see below). Prior to completing the scale and translation task, all participants took part in the lexical decision experiment of their respective L2. This was done so that the translation task, which was made up of all targets presented in the L2 experiment, was not viewed prior to participants' participation in the L2 experiment.

11.1.1 The Gradient Bilingual Dominance Scale

The Gradient Bilingual Dominance Scale (Dunn & Fox Tree, 2009) contains 12 questions (see Appendix 6) relating to second language exposure and experience. As such, the Gradient Bilingual Dominance Scale is not a measure of language proficiency but only aims to assess language dominance. In the present application, positive scores (0 to 30) indicated German language dominance, whereas negative scores (0 to -30) indicated English language dominance. Scores above 10/-10 indicated that the participants' native language was their more dominant language, whereas scores between -5 and +5 indicated that participants were balanced, i.e. neither language was necessarily more dominant compared to the other. A score between -5 and -10, or 5 and 10, indicated the participant to be a reasonably balanced bilingual (Dunn & Fox Tree, 2009).

In the German (L1) – English (L2) group, participants obtained an average dominance score of 12.9 (range -1 to 24), with 10 of 40 participants scoring below 10. This indicates, with respect to the Bilingual Dominance Scale only, that most participants had a tendency towards a German dominance. Out of all German native speakers, only 4 of 40 participants had started to learn both German and English at age six or below; the majority of participants (36) had not started to learn English before the age of 8 (see Table 32).

In the English (L1) -German (L2) group, the mean dominance score obtained was -22.5 (range -7 to -31), indicating that most participants had a clear English language dominance. Only 2 people obtained a dominance score below -20. Seven of the 26 participants were early bilinguals and had started to learn both languages at age six or below (compared to 19 who had started to learn German after the age of 8), indicating a greater proportion of early bilinguals than in the German-English group (27% versus 10%, respectively). Despite a greater proportion of early bilinguals in the English-German group, participants tended to be more strongly dominant in their native language rather than more balanced between English and German.

11.2.2 Difficulties Associated with Completion of Dominance Scale

All participants encountered some difficulties in completing the Gradient Bilingual Dominance Scale (Dunn & Fox Tree, 2009). Each participants had a least one query relating to an ambiguous meaning of a question. The most common issues are discussed below.

Participants had difficulty with the concept of specifying the age at which they first learnt their native language (questions 1 & 2), and further to specify when they felt comfortable speaking their native language (questions 3 & 4). The author suggested in both cases to choose an age in the lowest age range of 0-5 (the lowest scoring category, see Appendix 6) or to indicate 'native', which was later scored as'0-5'.

Further difficulties were associated with question 5 ('What language do you predominantly use at home'), as the question does not specify whether 'home' relates to the parental home or the current residence, which, for most German-English students, caused confusion. There was at least one participant who indicated to be living with a partner who only spoke the participant's L2, thus the current predominant language at 'home' was English, whereas the parental home language was the participant's L1. In fact, nine German participants who grew up in a German-only speaking home indicated they spoke 'English' at home, whereas none of the English native speakers indicated to be speaking 'German' at home unless they grew up bilingually (see also Table 32).

Although participants did not have queries in relation to question 7, the answers indicated that the question ‘If you have a foreign accent, which language(s) is it in?’ was often misunderstood. Specifically, 11 of the 40 German native speakers who had an apparent German accent in English (as judged by the author) indicated they had a foreign accent in German. Only 14 of the 26 participants in the English-German group responded to question 7. However, 8 of those 14 native English speakers indicated they had a foreign accent in English (Table 32). The remaining 12 English-German participants indicated that this question was not applicable to them, which suggests they understood this as having an accent in their own native language.

Further difficulties were associated with questions 9 and 10, asking how many years of schooling the participant had received in each respective language. The question itself does not specify whether schooling relates to the learning environment itself, i.e. attending a purely English or German school irrespective of the any foreign language tuition, or to the relative exposure a participant had to the respective language within an education context. Hence, some participants interpreted the question as meaning the former, and some as meaning the latter.

The response pattern suggests that if the Gradient Bilingual Dominance Scale is used in isolation, without follow up interviews to gather more information to interpret data, it may lead to both confusion and misrepresentation of the actual dominance in the respective languages of the participants. It is therefore possible that both German and English participants were either more, or less balanced than indicated by their dominance score.

Table 32. Summary of responses to questions 1, 2, 7, 9, 10, and 11.

	Mean age first learnt (range)		*Mean years of schooling in* (range)		*Foreign accent* (N)		*Loss of fluency* (N)	
	German	English	German	English	German	English	German	English
German Native (N=40)	*0.58* (0-6)	*10.48* (3-14, Outlier 39)	*12.89* (4-19)	*7.38* (1-15)	*11*	*25*	*8*	*2*
English Native (N=26)	*10.08* (1-17)	*0.38* (0-4)	*7.42* (2-13)	*13.06* (3-18)	*6*	*8*	*12*	*0*

11.2.3 Translation Measure

All participants completed a translation measure. All German L1 speakers were presented with the 90 target words of the English experiment (Experiments 1 and 2, see Appendix 8), and all English L1 participants were presented with the 90 target words of the German experiment (Experiments 3 and 4, see Appendix 9). For each correct translation one point was given. For translations of neighbour words, or deletion neighbours (e.g. translating widow as window) a half a point was assigned. Points were added up and converted into total percentage correct, with 90 points equating to 100%.

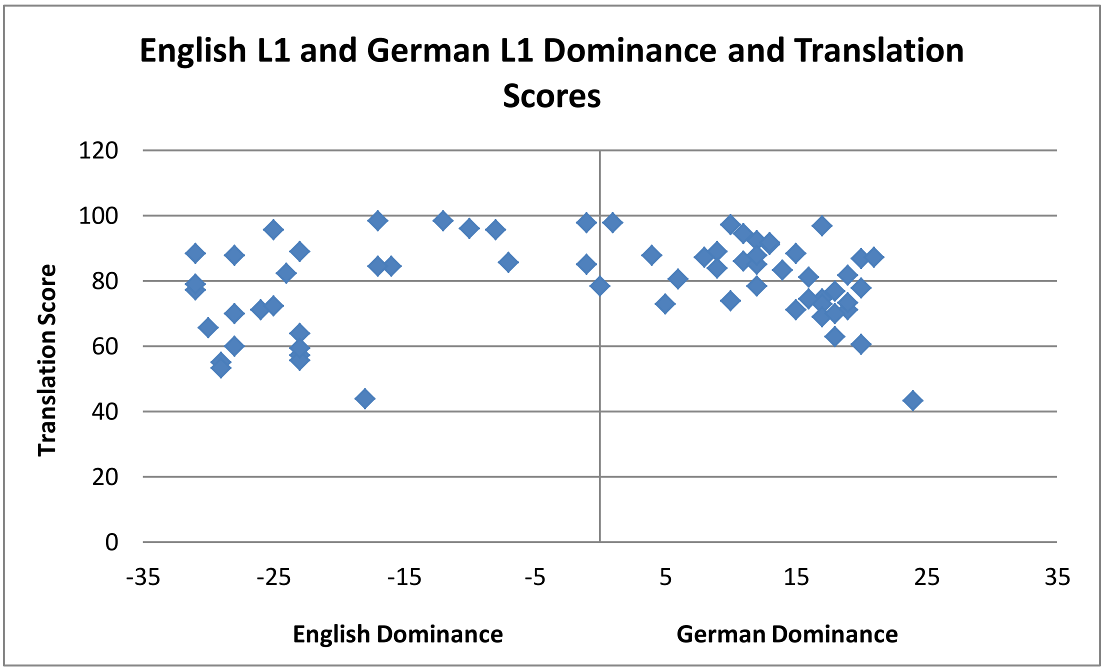
German (L1) – English (L2) participants obtained a mean correct translation score of 81% (range 43.3 – 97.8%), with only 3 participants scoring below 70% (43.3, 60.6, and 62.8% respectively). English (L1) -German (L2) participants obtained a mean translation score of 75.1% (range 43.9-98.3%), with 9 participants scoring below 70%, of which one scored below 50%. Despite the numerical difference in the mean translation scores, English L1 and German L1 bilinguals' translation scores did not differ significantly from each other [t(40.835)=1.452, n.s.].

11.2.4 Dominance Scale and Translation Measure

Inspecting Figure 27, it is apparent that the relationship between the dominance scale and the translation score is not linear, especially for English L1 speakers (left hand side of Figure 27). Therefore, a polynominal curve estimation model was computed for the combined data set of English L1 bilinguals, and German L1 bilinguals. The polynominal regression plotted the translation score against the language dominance score, and linear, quadratic and cubic models were fitted to the data to identify the best model fit for the relationship between dominance scores and translation scores.

The curve estimations regression revealed that the linear component made no significant contribution to the model [F(1,64)=1.886, p>0.05]. The linear component only explained 0.3% of the variance in the data (R^2 = 0.029). However, results showed a significant quadratic component of the model [F(2,63)=10.221, p<0.0001], with the translation scores being a significant predictor of the dominance score [t(62)=-4.49, p<0.01], explaining 24.5% of the variance in the data (R^2 =0.245). Additionally, the analysis also showed a significant cubic component of the model, [F(3,62)=8.65, p<0.0001; t(62)=-2.099, p<0.05], explaining 29.5% of the variation in the data (R^2 =0.295), thereby explaining and extra 5% in the variation of the data.

Figure 27. Curve estimation for translation scores plotted against dominance scores for English L1 – German L2 and German L1 – English L2 bilinguals.



Although overall the best performance on the translation task was obtained by balanced bilinguals, the Gradient Bilingual Dominance Scale (Dunn & Fox Tree, 2009) fails to be informative about so-called un-balanced bilinguals. Unbalanced bilinguals show translation scores from just over 40% to over 90%. It is not clear whether this variability in translation scores is related to issues with the scale itself (e.g., misinterpretation of the questions resulting in inflated or underestimated scores), or due to the fact that language dominance is not an informative measure in relation to bilingual language proficiency. In order to explore this issue further, the scale was revised and trialled with a new group of participants in Experiment 6.

11.3 Experiment 6

11.3.1 Revision of the Bilingual Dominance Scale

A revised version of the Gradient Bilingual Dominance Scale (Dunn & Fox Tree, 2009; see Appendix 7) was used to assess the language dominance of the German-English bilingual speakers in Experiment 6. Based on the results obtained with the original version of the Gradient Bilingual Dominance Scale in Experiments 2 and 4, several questions were revised and reworded in order to improve the comprehension of the scale. The following changes were made to scale (see Appendix 6 and 7 for a comparison):

1) Instructions were added for questions 1-3 (formerly questions 1-5); the opportunity to add different family members was provided for question 3 (formerly question 5).
2) Question 5 (formerly question 7) was reworded: old: 'If you have a foreign accent, which language(s) is it in?' - new: 'Do you have a noticeable foreign, non-native accent in English (German)?'
3) Question 6 (formerly question 8) was revised to include a variety of real-life social situations where language preference was to be stated (rather than presenting a hypothetical situation whereby one language had to be chosen for the remainder of the participant's life).
4) Question 7 (formerly questions 9 and 10) was reworded and the option of stating the number of years spent working in various environments was added. A new question was added in addition (question 8), asking for the

numbers of years the participant had lived in either a German or English speaking country.

All other questions remained unchanged.

11.3.2 Translation Task

As with Experiments 1-4, all participants of Experiment 6 were asked to complete a single word translation task. However, as the intention of revising the Dominance Scale was to ascertain whether its comprehension could be improved, the results had to be directly comparable to those of Experiment 2. Thus, the same translation task used for participants in Experiment 2 (presenting the targets of Experiments 1 and 2) was also used in Experiment 6.

11.3.3 The Gradient Bilingual Dominance Scale

All participants in Experiment 6 completed the Gradient Bilingual Dominance Scale. The German-English participants obtained an average dominance score of 10 (range -19 to 34), with 9 participants scoring below -1, indicating a more English than German language dominance, although all participants described themselves as German native speakers. Thirty-two participants obtained a score above 10, indicating a tendency towards German rather than English dominance. Thirteen participants obtained a dominance score between 1 and 10, indicating they were reasonably balanced in their dominance between English and German. Table 33 shows responses to questions that caused most difficulties in the original version of the Gradient Bilingual Dominance Scale (Experiment 2). None of the participants taking part in Experiment 6 needed any assistance in completing the scale. As can be seen, in comparison to answers provided for Experiment 2, the answers provided for Experiment 6, particularly the question of the numbers of years spent in purely German and English language environments, are more in line with what can be reasonably assumed for German native speakers studying at a UK university. The average number of years spent in a purely English learning environment was 3, compared to 7 for the unrevised questionnaire. Also, responses to the question of whether participants have a foreign accent resulted in responses that were in line with the experimenter's observation. Only four participants indicated to have a foreign accent in German. Other responses in the questionnaire indicated those participants to be early bilinguals. This contrasts with responses obtained with the unrevised scale, to which 11 German native speakers indicated to have a foreign accent in German.

Table 33. Summary of responses to questions 1, 2, 7, 9, 10, and 11.

	Mean age first learnt (range)		*Mean years of schooling in* (range)		*Foreign accent* (N)		*Loss of fluency* (N)	
	German	English	German	English	German	English	German	English
German Native (N=54)	0 (0-7)	9 (0-14)	12 (0-20)	3 (0-13)	4	34	30	12

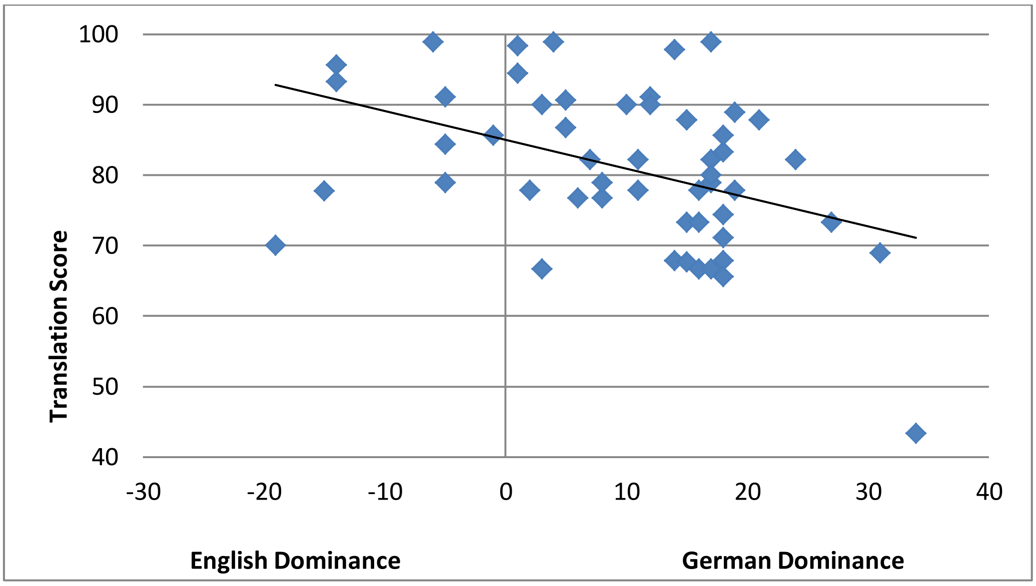
11.3.4 Translation Measure

All participants completed a translation measure, identical to that of Experiment 2 (see Appendix 8). The translation measure consisted of all 90 target words presented in Experiments 1 and 2. For each correct translation one point was given. For translations of neighbour words, or deletion neighbours (e.g. translating widow as window) a half a point was assigned. Points were added up and converted into total percentage correct, with 90 points equating to 100%. Participants achieved an average of 81% (range 43.4 – 98.9). Ten out of 54 participants scored between 65% and 70%, with only one participant scoring below 50%.

11.3.5 Dominance Scale and Translation Measure

A polynominal regression model was computed to describe the relationship between the revised version of the Gradient Bilingual Dominance Scale and the translation measure. The curve estimations regression revealed a significant linear trend [F(1,52)=10.910, p<0.01], explaining 17.3% of the variance in the data (R^2=0.173). There was also a significant quadratic trend [F(2,51)=10.709, p<0.001], explaining a further 12.3% of the variance in the data (R^2=0.29.6). In addition, there was a significant cubic trend in the data [F(2,50)=7.000, p<0.01], although the cubic trend did not explain any additional variance in the data (R^2=0.29.6) (see Figure 28).

Figure 28. Curve estimation for translation scores plotted against language dominance scores for Experiment 6 – German L1 – English L2 bilinguals.



The above analysis indicates that the Graded Bilingual Dominance Scale is not a very informative measure in relation to L2 proficiency. Improving comprehension did not lead to an increase in the amount of variance that can be accounted for in the data. In the original version of the dominance scale, 25.9% of the variance could be accounted for by the translation score. Only 3.7% more variance (29.6%) was accounted for following the revision of the scale. Apart from one data point that shows an unbalanced, German dominant participant who obtained the lowest translation score, the dominance scale does not appear to be a useful instrument in accounting for differences in language proficiency. Thus, more objective tests, such as the translation test used in this work, or other standardised proficiency tests such as LexTale (Lemhöfer & Broersma, 2011), may be more appropriate tools in assessing L2 proficiency of bilingual speakers.

Chapter 12

Discussion

12.1 Main Findings

The work presented in this thesis reports on early morphological visual word processing in English L1 - German L2 and German L1 - English L2 bilingual speakers, and contributes to our understanding of bilingual morphological word processing, as well as cross-language effects. The findings indicated that bilingual English L1 and English L2 speakers show strong priming effects for prime-target pairs that are both morphologically and semantically related (e.g., *teacher* - *TEACH*), only pseudo-morphologically related (e.g., *corner* – *CORN*), and only orthographically related (e.g., spinach – SPIN). Monolingual English speakers on the other hand only showed strong priming effects for prime-target pairs that were both morphologically and semantically related. Specifically, Experiments 1 and 2 demonstrated that English L1 and L2 speakers show comparable priming magnitudes for form, opaque, and transparent items. Experiments 3 and 4 investigated whether the same bilingual speakers who demonstrated comparable priming magnitudes across all conditions in Experiments 1 and 2 make use of similar word processing strategies in their other known language, German. Results suggested that participants do not appear to use the same strategies. German L1 – English L2 speakers only showed strong priming effects for transparent prime-target pairs, whereas English L1 – German L2 speakers showed comparable priming magnitudes for transparent and opaque items.

Experiments 5 and 6 sought to ascertain whether the large form priming effects obtained in Experiments 1 and 2 could be attributed to prime frequency effects.

However, results demonstrated that prime frequency could not account well for the large form priming effect obtained in previous experiments. Further, and in contrast to Experiment 1, Experiment 5 demonstrated a graded priming effect for English native speakers, with most priming for transparent items, moderate opaque priming, and little form priming. Conversely, Experiment 6 replicated the trend established in Experiment 2, and revealed that English L2 speakers with German as L1 show comparable priming magnitudes across all conditions. Experiment 7 sought to establish whether the large form priming effects obtained in Experiment 1 were driven by the bilingual status of the participants, rather than by the properties of the items themselves. Testing monolingual English speakers only, Experiment 7 established that the knowledge of a second language appears to influence the way all words of an apparent ‘stem+suffix-like-ending’ are processed, resulting in rapid decomposition thereof. Therefore, results suggest that the ability to proficiently speak a second language affects L1 processing, even at the earliest stages of visual word processing. The results of this thesis are also summarised in Table 34.

Table 34. Summary table for results of all experiments of this thesis.

Experiment / Target Language	Participants	Findings
1/ English	English L1 bilinguals (with German L2)	Comparable priming across form (20ms), opaque (20ms), and transparent (35ms) items
2/ English	English L2 bilinguals (with German L1)	Comparable priming across form (33ms), opaque (17ms), and transparent (33ms) items
3/ German	German L1 bilinguals (with English L2)	Large transparent priming (50ms), minimal opaque priming (5ms), moderate form priming (16ms)
4/ German	German L2 bilinguals (with English L1)	Large transparent (44ms) and opaque priming (45ms); form inhibition (-12ms)
5/ English	English L1 native speakers	Graded priming effect, most priming for transparent items (25ms), moderate priming for opaque items (13ms), and least for form items (6ms)
6/ English	English L2 bilinguals (with German L1)	Comparable priming across form (18ms), opaque (20ms), and transparent (29ms) items; no clear effect of prime frequency on priming
7/ English	English L1 monolinguals	Most priming for transparent items (33ms), inhibition for opaque (-8ms) items, minimal inhibition for form items (-1ms)

12.2. Cross-lingual Effects in Bilingual Visual Word Processing

As already outlined in Chapter 5, in comparison to the vast amount of research into native language processing, there is relatively little overall research into bilingual visual word processing, and thus, the way the human brain is able to control activation of one language whilst speaking the other is still poorly understood. In relation to morphological processing, the majority of bilingual research undertaken to date has primarily focused on the effects of L1 on L2 (e.g., Diependaele et al., 2011; Lehtonen, Niska, Wande, Niemi, & Laine, 2006; Lehtonen et al., 2009; Lemhöfer et al., 2008; Portin et al., 2008). As a result, contradicting conclusions have been drawn, such as that "… L2 processing… is fundamentally different from word processing in L1" (Lemhöfer et al., 2008; p. 27), or that the processing of "…morphologically complex words occurs along similar principles and to the same degree in L1 and L2 processing" (Diependaele, Duñabeitia, Morris, & Keuleers, 2011; p. 356).

The results of the present work suggest that both bilinguals' L1 and L2 processing may be different from monolinguals' native language processing. This indicates that even when L2 proficiency is high, L2 processing may not necessarily become more native-like, as for example suggested by previous research (e.g., Diependaele et al., 2011; Lehtonen et al., 2006). Rather, the results of the experiments in this thesis reveal a trend that suggests that both L1 and L2 processing differs from monolingual word processing, even at the earliest stages of visual word processing. This issue has not previously been explored in relation to morphological processing, and as such, this thesis has begun to address an important gap in empirical knowledge. As Experiment 5 demonstrated, native English speakers show a more graded effect of morphological processing, with most priming for transparent items (25ms), moderate priming for opaque items (16ms), and negligible priming for form items (6ms). These results are consistent with the native English speaking control group used by Diependaele et al. (2011) (Experiment 1; 36ms, 15ms, 1ms, respectively). It is important to note, however, that just as in Experiment 5 of this work, Diependaele et al. (2011) did not control for second language knowledge of their native English control group. When second language knowledge is controlled for, as was done in Experiment 7 of this thesis, true monolingual speakers still show most priming for transparent items (33ms), but no longer show facilitation for opaque items (-8ms). The trend for English L1 bilingual speakers (Experiment 1), however, is very different. Decomposition appears to take place for all items that contain nested whole words, even when they are clearly monomorphemic (e.g., *freeze*). Highly proficient English L2 speakers demonstrate the same trend (Experiments 2 and 6) as bilingual L1 speakers, again with large facilitations for all words containing nested whole words, regardless of whether these are truly morphological or monomorphemic. It is therefore plausible to assume that it is the bilingual status of the participants, and the knowledge of a second language, that influences L1 processing. This indicates then that there may be cross-lingual processes that potentially influence bilingual morphological processing, not only from L1 to L2 as already demonstrated in the literature (for an overview see Chapter 5), but also from L2 to L1.

The fact that bilingual visual word processing is non-selective has already been suggested in the BIA and BIA+ models (Dijkstra & Van Heuven, 2002; Van Heuven et al., 1998), and a growing number of neurological studies support the notion that bilinguals make use of shared cortical areas for both L1 and L2 (see Chapter 5). However, the extent of L2’s influence upon L1, and at what level of proficiency L2 begins to influence L1 processing, is not very well understood. At present, there are no studies in relation to morphological processing that explore cross-lingual effects. The few studies that have explored L2 effects on L1 have often done so in a context of L1 attrition (loss of L1 fluency) due to prolonged L2 exposure. For example, Gürel (2004) found that Turkish L1 speakers who had spent most of their adult life immersed in an English language environment applied English binding procedures to overt Turkish pronouns. Similarly, Dussias (2004) found that Spanish L1 – English L2 speakers who had been living in an English speaking environment for over three years favoured English sentence parsing strategies (low attachment of the relative clause to the noun phrase) when reading Spanish sentences, whereas Spanish monolingual speakers preferred a high attachment sentence parsing strategy. Consequently, Dussias (2004) argued that the influence of L2 on L1 parsing strategies may develop more rapidly (after only three years) than often suggested in the literature. Recent evidence from experiments using event-related-potentials (ERPs) (Takahashi et al., 2011) indicates that the influence of L2 on L1 semantic processing is detectable by ERP measure in children as young as age five, after a relatively short amount of exposure to L2 (320 hours).

More recently, experiments exploring the non-selective account of bilingual word processing have done so in relation to homophone and cognate processing, both within a sentence context (Van Assche et al., 2009) and an auditory context (Lagrou, Hartsuiker, & Duyck, 2011). Van Assche et al. (2009) found that for Dutch L1 speakers, knowledge of English aided the recognition of Dutch-English cognates in a monolingual Dutch task. Lagrou et al. (2011) on the other hand demonstrated that auditory recognition of Dutch-English homophones was significantly slower for Dutch L1 – English L2 speakers compared to monolingual English controls, regardless of the overt language context of the experiment. Despite the difference in findings, both experiments suggest that bilingual word processing is non-selective in both the visual and the auditory modality, indicating that cross-lingual influences in bilingual speakers are both involuntary and salient.

In relation to the experiments presented in this thesis, the findings presented are more in line with a language non-selective account, rather than the view that there are separate lexicons for L1 and L2 (e.g., Kroll & Stewart, 1994). As the BIA (Van Heuven et al., 1998) and BIA+ models (Dijkstra & Van Heuven, 2002) outlined, at the early stages of visual word processing, bilingual language processing is first and foremost non-selective. In practical terms, this means that for any language task, may this be in a native or second language context, bilinguals have to accurately select the correct word from a much larger pool of possible words than monolinguals, ultimately leading to increased processing costs, and increased lexical competition. The processing costs incurred by bilingual speakers have sometimes been outshone by findings demonstrating that knowledge of a second language may have demonstrable advantages. For example, Bialystok, Craik, and Luk (2008) found that bilinguals outperform monolinguals on tasks requiring the inhibition of distractors, thereby demonstrating much more developed executive control, potentially stemming from the fact that bilinguals have to supress the activation of the other known language in any monolingual context. However, despite these apparent advantages in terms of executive control, the overall reaction times of the experiments presented in this work suggest that bilingual speakers may incur processing costs in both L1 and L2.

The majority of bilingual studies reviewed in this thesis (see Chapter 5) found bilinguals to be slower in their overall reaction times than native speaking control groups. This was also demonstrated by Experiments 1 to 4 in this work (see Table 35). Specifically, English L2 speakers (Experiment 2) were, on average, 66ms slower compared to English L1 bilinguals (Experiment 1). In addition, Experiment 3 and 4 showed that German L2 speakers were, on average, 85ms slower than German L1 bilinguals. Interestingly, Experiment 7 demonstrated that being bilingual may also significantly impact on native language processing speed. Monolingual English speakers (Experiment 7) were, on average, 75ms faster in making lexical decisions compared to English L1 bilinguals (Experiment 1).

Table 35. Mean reaction times for experiments 1,2,3,4, and 7 in this thesis.

Experiment	*Participants*	*Mean Reaction times*
1	English L1 bilinguals (with German L2)	695ms
2	English L2 bilinguals (with German L1)	761ms
3	German L1 bilinguals (with English L2)	718ms
4	German L2 bilinguals (with English L1)	803ms
7	English L1 monolinguals	620ms

These findings are in line with the non-selective account of bilingual visual word processing. In monolingual speakers, lexical competition is constrained by the number of words an individual knows in their own language. For bilingual speakers, this process is complicated by the size of the combined lexica of both L1 and L2, effectively doubling the size of the lexicon (at least at a high level of L2 proficiency). Thus, before the correct word node is selected, lexical competition takes place in a non-selective fashion across both languages at the feature and letter level (see also Dijkstra & Van Heuven, 2002). Further complications may arise for bilinguals of German and English due to the number of homographs and cognates shared between these two languages (this also limited the types of stimuli that could be selected for Experiments 1-4, as described in Chapter 6). Owing to the large number of possibilities at the feature and letter level, it appears that bilinguals incur significant processing costs. As bilingual word processing is non-selective, these processing costs would then be apparent in both L1 and L2 contexts. Thus, the experiments in this thesis point towards the possibility that there are processing costs for bilingual speakers in both their respective languages. It would be of interest to systematically explore whether bilingual speakers are indeed slower in their native language compared to monolingual controls. In addition, it would be interesting to study whether processing costs increase with the addition of a third or fourth language, or whether the bilingual / multilingual brain is able to develop word processing strategies that limit the impact of a very large pool of lexical possibilities on lexical competition.

12.3. Bilingual Morphological Word Processing – Same or Different?

This thesis primarily aimed to address the important question of whether bilingual morphological processing is akin to native language processing or whether native and second language morphological processing is different. The findings of this thesis indicated second language morphological processing to be different from native language processing, contrasting the conclusions drawn in previous studies that made use of a similar methodology (e.g., Diependaele et al., 2011). In relation to the English language, Experiment 2 showed comparable priming magnitudes for all conditions, whereas Experiment 7 with monolingual controls demonstrated that morphological decomposition only takes place for items containing a semantically transparent morphological structure. For German, Experiments 3 and 4 demonstrated that German L2 speakers show decomposition for both transparent and pseudo-morphological items, whereas form control items resulted in moderate inhibition. German L1 bilinguals on the other hand only showed decomposition for semantically transparent items, in addition to some moderate form priming (see also Table 34, p. 238). It is difficult to place the German findings, and the fact that German L2 speakers, but not German L1 speakers, were more in line with the Rastle et al. (2004) data, into a context of other German language experiments. This is due to the fact that this methodology (distinguishing between transparent, opaque, and form items) has not previously been employed for the German language. The difficulty with the German data also lies in the absence of a true monolingual control group. The findings of this thesis suggest that native language control groups should be tightly controlled for, and at best, only include true monolingual speakers, as the knowledge of a second language appears to have an impact on L1 processing, as outlined above. Thus, in order to be able to draw meaningful conclusions as to whether German L2 speakers process morphologically complex items akin to German monolingual speakers, it would have been desirable to have included a monolingual German control. This would have also provided an important insight into whether the English language findings (that L2 knowledge appears to influence L1 processing) can be generalised to other languages as well.

However, finding a monolingual German group matched for age and education is almost impossible, as most German children are exposed to English from the age of 8, and English as a foreign language was made a compulsory subject from primary school through to university in all German states in the early 1990s[15].

Nevertheless, the findings of this thesis, at least for the English language, suggest that bilingual speakers are more likely than monolingual speakers to apply decomposition strategies to all words containing nested whole words, regardless of the semantic transparency between the stem and the apparent suffix-like ending. These findings contrast with other studies. For example, Silva and Clahsen (2008) claimed that English L2 speakers, irrespective of the script of their L1, do not decompose morphologically complex items, but rather process them as whole word entities. Thus, the authors did not observe any priming in English L2 speakers for morphologically complex items. However, due to the very small range of suffixes selected in their experiments (see Chapter 5), it is difficult to generalise these claims across the breadth and depth of English morphology (see Chapter 1). A recent review on bilingual morphological processing (Clahsen et al., 2010) argued strongly that L2 morphological processing differs from L1 morphological processing, regardless of L2 proficiency and similarity between L1 and L2. The results of this thesis would agree with these conclusions. However, the majority of experiments conducted by Clahsen and colleagues have made use of a rather limited range of suffixes (such as –nes; –ity, –ed and -t) and have consistently found less priming in

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[15] True monolingual German speakers can still be found in some regions of Germany, predominantly those of former East Germany (the newer German states), where English was not part of the curriculum until the early 1990s. However, the majority of true German monolingual speakers are now over 50 years of age.

L2, arguing in favour of whole-word processing strategies rather than a decomposition approach in L2 (e.g., Clahsen & Neubauer, 2010; Clahsen et al., 2010; Silva & Clahsen, 2008). On the other hand, the findings by Diependaele et al. (2011) suggest the English L2 speakers are more native-like in their approach to morphologically complex items, although it has not be noted here that much higher form priming levels (14ms) were observed for English L2 speakers only. However, Diependaele et al. (2011) argue in favour of a graded semantic effect, resulting in more priming for semantically transparent than semantically opaque items, akin to the pattern observed with native English speakers in Experiment 5 of this thesis. However, the bilingual data from the English experiments (Experiments 1, 2, and 6) in this thesis (see Table 34, p. 238) do not support this assumption. Rather, the data here suggest that semantic factors play a minor role in early bilingual morphological visual word processing. In fact, the findings of Experiment 6 replicated the findings of Experiment 2 for a larger sample of English L2 speakers (54 participants) and a larger number of observations per condition (45), demonstrating that English L2 speakers with German as L1 apply decomposition strategies to all words of an apparent 'stem+suffix-like-ending', regardless of semantic transparency or frequency.

In sum, it can be said that the results of the experiments in this thesis indicate that bilingual speakers do not appear to make use of the same processing strategies for morphologically complex items as native or monolingual speakers. Rather, the results for German native speakers (Experiment 3) and English monolingual participants (Experiment 7) suggest that semantic factors may play a more contributing role in monolingual morphological processing (see also Feldman et al., 2009). On the other hand, semantic factors appear less important for L2 processing, as demonstrated for English L2 (Experiments 2 and 6) and German L2 (Experiment 4) speakers. Overall, however, it has to be noted that none of the experiments in this thesis replicated the findings of Rastle et al. (2004), which demonstrated equal priming for transparent and opaque items, and no facilitation for form items. As can be seen in Table 34 (pg. 239), experiments with English as target language demonstrated that bilinguals show equal priming magnitudes in all conditions, suggesting that all words containing nested whole words may undergo a process of decomposition into ‘stem+plus suffix-like ending’ (Experiments 1,2, and 6). On the other hand, English native speakers (Experiment 5) show a more graded process of priming, allowing for the possibility of a mediating role of semantics, as suggested by Diependaele et al. (2011). However, results with monolingual English speakers only (Experiment 7) suggest that semantic factors play an important role in monolingual morphological processing, and that pseudo-morphological primes are not treated akin to transparent morphological primes. Thus, the findings of all English language experiments presented in this thesis are difficult to reconcile with the findings and interpretations presented by Rastle et al. (2004). It would therefore be of interest to re-test the Rastle et al. (2004) stimuli with a group of complete monolingual English speakers in order to see whether the differences between the present experiments and the Rastle et al. (2004) data are due the participants’ language status (i.e., it is possible that some participants who took part in the Rastle et al. (2004) study knew more than one language), or due to differences in the relative frequencies of primes and targets for the present experiments and the Rastle et al. (2004) study. However, the results of Experiment 5 and 6 (see below) indicate that the relative frequency between primes and targets does not play an important role in morphological processing.

12.4. Frequency Effects on Morphological Processing

The surprisingly large form priming effect obtained in Experiments 1 and 2 led to the assumption that prime frequency effects may have mediated the role of morphological and semantic factors, at least for the English language. This assumption has been made elsewhere. For example, Diependaele et al. (2011) hypothesised that '*... priming will become larger for transparent, but not opaque items, the higher the prime word frequency is … studies with relatively low frequency primes and low frequency target neighborhoods should have a better chance of observing matched facilitations across transparent and opaque items* ' (p. 356). Thus, Experiments 5 and 6 set out to explore the influence of prime frequency on priming magnitude in relation to morphological processing. In the first instance, Experiment 5 demonstrated that for native English speakers, prime frequency did not cause large variations for morphological items in terms of priming magnitude, although a more graded effect of semantic transparency was apparent between semantically transparent and opaque items. For transparent items, high frequency primes resulted in somewhat less priming (25ms) than low frequency primes (38ms); for opaque items, this difference was negligible (15 and 13ms, respectively). Priming magnitudes differed little between transparent and opaque items when prime and target were of similar medium frequency (14 and 9ms, respectively). For form items, priming patterns were more varied, but in line with the literature on monomorphemic items. For example, Segui and Grainger (1990) found that primes higher in frequency than their respective targets cause an inhibition of target recognition. This pattern was also observed for high frequency form primes in Experiment 5 of this thesis. Overall however, prime frequency could not account well for the priming patterns observed. Thus, the results somewhat contradict the above hypothesis stated by Diependaele et al. (2011). As already demonstrated for transparent items by McCormick et al. (2009), prime frequency does not appear to mediate priming magnitudes in morphologically complex items. Experiment 5 demonstrated that the same is also observed for pseudo-morphological items. Although for form items clear variations in the magnitude of priming were observed across frequencies, again, overall prime frequency could not account well for the variation in priming magnitudes, thereby offering no plausible explanation for the priming patterns observed in Experiment 1. Having established the role of prime frequency in native speakers, Experiment 6 sought to explore the effect of prime frequency in bilingual English L2 speakers. Here again, some variation was observed across conditions, although for semantically transparent items, there was consistent priming across low, medium, and high frequencies (38, 20, and 29ms, respectively). Most variation was observed for semantically opaque items (14, 47, and -4ms for low, medium and high frequency primes, respectively), whereas for form control items, only low frequency primes resulted in negligent priming (5ms), and consistently high priming was observed for targets preceded by medium (22ms) and high (29ms) frequency primes. Again, overall, prime frequency could not account well for the priming magnitudes observed. The literature on frequency effects in bilingual visual word processing is sparse, in particular in relation to morphological processing. It is therefore difficult to place these results in the context of other findings. A few studies that have been conducted in relation to word frequency (e.g., Lehtonen & Laine, 2003; Lehtonen et al., 2006; Portin et al., 2008) found that bilinguals are slower to react to low frequency items, which was also observed in Experiment 6 of this work (see Table 26). None of these studies, however, are directly relevant to the debate surrounding semantic transparency effects. In sum then, it can be said that Experiments 5 and 6 provided little indication that prime frequency can account well for the priming magnitudes observed in Experiments 1 and 2 (see also Figures 18-20, Chapter 8, and Figures 21-33, Chapter 9). Rather, as outlined above, it appears that the bilingual status of the participants, and the large competition between items from two languages caused by the non-selective processing strategy of the bilingual brain, are primarily driving the priming effects observed in the experiments of this work.

12.5 Limitations and Future Directions

As already briefly outlined in Chapter 6, owing to the sample size (particularly in relation to Experiments 1 and 4) and number of observations per condition, the experiments may have been somewhat underpowered and thus should be placed in the context of the sample sizes and numbers of observations per conditions of other studies making use of the same or a similar methodology. Table 36 provides an overview of all experiments in this work with corresponding sample sizes and numbers of observations. Table 37 then provides comparable data for studies using the same or similar methodologies (all of these studies make a distinction between semantically transparent and opaque morphological items, and in most cases, orthographic form control items).

Table 36. Overview of sample sizes and numbers of observations of experiments in this work.

Experiment	Number of Participants	Number of prime-target pairs per condition	Observations per condition
1	26	30	15
2	40	30	15
3	40	30	15
4	26	30	15
5	60	90	45
6	54	90	45
7	40	30	15

On comparing Tables 36 and 37, it is evident that Experiments 1 and 4 of this work contained a smaller number of participants than most studies that have made use of a similar methodology. However, it has to be emphasised here that the desired number of participants for Experiments 1 and 4 was 40, in order to match sample sizes with Experiments 2 and 3. Owing to difficulties in recruiting English native speakers with fluent German as L2, 26 individuals volunteered to take part in the experiments. With respect to the numbers of observations per condition, although on the smaller end, it appears that 15 observations per condition is not unusual for the methodology employed (see Table 35). However, it is important to emphasise here that the number of observations per condition that could be created for the English language experiments (Experiments 1 and 2), were somewhat constrained by the number of observations per condition that could be created for the German experiments (Experiments 3 and 4). As already outlined in Chapter 4, and Chapter 7, the German language contains a limited number of monomorphemic items. Thus, the number of stimuli in the German form condition (30), made up of monomorphemic words that contain nested whole words, exhausted the possible number of form items (in terms of matching neighbourhood size, frequency, and length to opaque and transparent items) present within the German language. Thus, in order to compare bilingual speakers in both languages, it was important that both the German and English experiments contained the same number of observations per condition.

Further, as shown in Table 36, it becomes apparent that Experiments 5 and 6 of this work contain by far the largest number of observations per condition, matched by no other study distinguishing between transparent, opaque, and form items. Here, the sample sizes were large and typical for the methodology employed (see Table 37).

Table 37. Overview of sample sizes and numbers of observations of studies using the same or a similar methodology as experiments in this work.

Study	Number of Participants	Number of prime-target pairs per condition	Observations per condition
Duñabeitia et al. (2011)			
Experiment 2	34	42	21
Diependaele et al. (2011)			
Experiment 1	65	50	25
Experiment 2	66	50	25
Experiment 3	65	50	25
Feldman et al. (2009)	88	40	20
McCormick et al., (2008)			
Experiment 1	46	50	25
Experiment 2	58	30	15
Rastle et al. (2004)	62	50	25
Longtin et al. (2003)			
Experiment 1	36	30	15
Experiment 2	33	30	15

It can therefore be argued that owing to the relatively small sample size for both Experiment 1 and 4, and the possibility of diminished statistical power, it would be desirable to replicate Experiments 1-4 in a larger sample of bilingual speakers of German and English. The difficulties in recruiting a German monolingual control group have already been outlined above. Given the fact that recruiting a German monolingual control group matched for age and education may not be achievable, it may be desirable to focus on another language, such as Spanish, Italian, or Polish, for which true monolingual control groups matched for age and education can be found.

Of course one must be cautious to generalise the findings of this thesis to any languages other than the ones that were explored in this work. As Experiments 3 and 4 demonstrated, certain elements of visual word processing, and the contribution of semantic factors in morphological decomposition, may be language specific. Thus, the overarching conclusion that bilingual speakers do not appear to use the same processing strategies as monolingual speakers needs to be explored in the context of other languages. Possibly the most interesting result of this thesis, the findings that the knowledge of a second language appears to affect the way L1 is processed, and appears to impact significantly on L1 processing speed, needs to be studied in larger samples, and across different languages. This work has demonstrated that bilinguals are different from monolinguals in two ways: processing strategies in bilinguals' L2 differ from those of monolingual speakers; and processing strategies in the bilinguals' L1 change as a consequence of L2 knowledge. The impact of L2 knowledge on L1 processing, leading to increased lexical competition, and significant delays with respect to lexical decisions, should be explored further. Since the majority of people in today's world are bilingual or multilingual speakers, it would be of great interest to further explore the impact of L2 on L1. It has already been established that L1 influences L2 processing. In the light of this work's findings, however, the more interesting aspect of bilingual visual word processing appears to be L2s' influence on native language processing, with important implications for working memory load, and visual and verbal speech processing.

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Appendices

Appendix 1: English Affixes

Selection of common English prefixes and suffixes, taken from Marchand (1969).

Prefix	Suffix	Suffix Frequency in CELEX (where available)
a-	-able	5
ante-	-acy	162
anti-	-age	388
arch-	-al	177
auto-	-an	174
be-	-ance	52
bi-	-ancy	178
circum-	-ant	17
cis-	-ard	
co-	-are	19
counter-	-arian	123
crypto-	-ary	352
de-	-ate	903
demi-	-ation	
di-	-by	191
dis-	-cy	22
em-	-dom	69
en-	-dy	253
epi-	-ed	91
ex-	-ee	31
extra-	-een	36

fore-	-eer	207
hyper-	-en	232
in-	-ence	93
inter-	-ency	471
intra-	-ent	2182
mal-	-er	4
meta-	-erel	149
micro-	-ery	32
mid-	-ese	7
mis-	-esque	108
mono-	-ess	42
mulit-	-et	19
neo-	-ette	19
non-	-ety	11
pan-	-fold	191
para-	-ful	71
per-	-fy	33
post-	-hood	17
pre-	-i	107
preter-	-ian	
re-	-iana	396
retro-	-ic	8
semi-	-ician	51
step-	-ie	200
sub-	-ify	1

super-	-ikin	286
supra-	-in	171
sur-	-ine	63
trans-	-ing	129
tri-	-ish	247
twi-	-ism	376
ultra-	-ist	21
un-	-ister	34
uni-	-ite	667
vice-	-ity	234
	-ive	872
	-ize	44
	-kin	87
	-le	206
	-less	46
	-let	57
	-ling	2994
	-ly	414
	-ment	4
	-mo	21
	-most	1281
	-ness	98
	-ory	213
	-ous	6

-rel	70
-ry	101
-ship	37
-some	38
-ster	14
-sy	60
-th	4
-ton	48
-ty	73
-ure	28
-ward(s)	1563
-y	5

Appendix 2: German Affixes

Selection of common German prefixes and suffixes, taken from Eisenberg, Gelhaus, Henne, Sitta, and Wellman (1998)

Prefix	**Suffix**	**Suffix Frequency in CELEX (where available)**
a-	-abel	57
ab-	-age	145
an-	-al	303
auf-	-ant	164
aus-	-anz	24
be-	-ar	31
bei-	-är	
de-	-ation	667
des-	-ator	14
dis-	-atur	15
durch-	-bar	380
ein-	-bold	5
ent-	-e	533
entgegen-	-ei	480
er-	-ell	120
fehl-	-ement	9
ge-	-ent	89
hinter-	-enz	49
in-	-er	2325
los-	-erei	167
miss-	-erie	5
mit-	-eur	11

nach-	-euse	6
non-	-frau	18
über-	-heit	352
um-	-iat	12
un-	-ig	2068
unter-	-ik	72
ver-	-iker	29
vor-	-isch	1258
wider-	-ismus	181
wieder-	-ist	681
zer-	-ität	
zu-	-iv	158
zurecht-	-ler	39
	-lich	940
	-ling	43
	-mann	59
	-nis	116
	-os	285
	-ös	
	-sam	68
	-schaft	97
	-tum	40
	-ung	2550
	-zeug	31

Appendix 3: Stimuli Experiments 1 and 2

Condition	**Target**	**Related Prime**	**Unrelated Prime**
FORM	arch	archaic	earthly
FORM	bamboo	bamboozle	melodious
FORM	basil	basilica	mandolin
FORM	blur	blurb	vinyl
FORM	butt	buttress	pendulum
FORM	chance	chancellor	ingredient
FORM	counter	counterfeit	benevolence
FORM	crow	crowd	dozen
FORM	deter	detergent	indicator
FORM	dial	dialect	capsule
FORM	drive	drivel	citrus
FORM	enter	entertain	scattered
FORM	force	forceps	uterine
FORM	forest	forestall	dissident
FORM	free	freeze	polish
FORM	germ	germane	topical
FORM	heart	hearth	racist
FORM	infer	inferno	geology
FORM	opera	operate	display
FORM	pier	pierce	rooted
FORM	place	placebo	menthol
FORM	plain	plaintiff	telegraph
FORM	quart	quartz	boffin

FORM	salmon	salmonella	distillery
FORM	since	sincere	crimson
FORM	sombre	sombrero	aperitif
FORM	stir	stirrup	dungeon
FORM	tomb	tomboy	lyrics
FORM	trap	trapeze	glutton
FORM	wren	wrench	injure
OPAQUE	adult	adultery	protocol
OPAQUE	barb	barber	plight
OPAQUE	both	bother	switch
OPAQUE	buzz	buzzard	cordial
OPAQUE	candid	candidacy	meteoroid
OPAQUE	casual	casualty	follower
OPAQUE	coast	coaster	bullion
OPAQUE	count	country	problem
OPAQUE	earl	early	slope
OPAQUE	feud	feudal	edible
OPAQUE	fleet	fleeting	pastoral
OPAQUE	flour	flourish	charming
OPAQUE	gloss	glossary	dumpling
OPAQUE	infant	infantry	betrayal
OPAQUE	invent	inventory	millennium
OPAQUE	iron	irony	surge
OPAQUE	liquid	liquidate	electrify
OPAQUE	marsh	marshal	antenna

OPAQUE	moth	mother	change
OPAQUE	pluck	plucky	ageing
OPAQUE	plum	plumage	latency
OPAQUE	secret	secretary	communist
OPAQUE	snip	sniper	oracle
OPAQUE	sting	stingy	venous
OPAQUE	string	stringent	fervently
OPAQUE	stuff	stuffy	robust
OPAQUE	supple	supplement	percentage
OPAQUE	trait	traitor	summary
OPAQUE	treat	treatise	mortuary
OPAQUE	whisk	whisker	lottery
TRANSPARENT	alien	alienate	informed
TRANSPARENT	beef	beefy	tacit
TRANSPARENT	combat	combatant	trickster
TRANSPARENT	defend	defendant	excursion
TRANSPARENT	defer	deference	barbarian
TRANSPARENT	diet	dietary	sensual
TRANSPARENT	dream	dreamer	martian
TRANSPARENT	employ	employer	contrast
TRANSPARENT	enjoy	enjoyable	ambiguous
TRANSPARENT	evict	eviction	roadster
TRANSPARENT	filth	filthy	coarse
TRANSPARENT	flesh	fleshy	rustic
TRANSPARENT	fluff	fluffy	inborn

TRANSPARENT	froth	frothy	impure
TRANSPARENT	gloom	gloomy	daring
TRANSPARENT	green	greenery	importer
TRANSPARENT	guard	guardian	literacy
TRANSPARENT	guilt	guilty	shroud
TRANSPARENT	humid	humidity	provider
TRANSPARENT	insist	insistent	contented
TRANSPARENT	knock	knocker	lineage
TRANSPARENT	mourn	mourner	protégé
TRANSPARENT	myth	mythical	volatile
TRANSPARENT	preach	preacher	ignition
TRANSPARENT	quiet	quieten	upgrade
TRANSPARENT	self	selfish	vicious
TRANSPARENT	splash	splashy	prudish
TRANSPARENT	steam	steamer	honesty
TRANSPARENT	wealth	wealthy	passive
TRANSPARENT	widow	widowed	haughty

Appendix 4: Stimuli Experiments 3 and 4

Condition	**Target**	**Related Prime**	**Unrelated Prime**
FORM	Affe	Affekt	Zauber
FORM	Alge	Algebra	Jackett
FORM	Blei	Bleib	prima
FORM	flau	Flaum	Larve
FORM	Geste	Gestern	maximal
FORM	Herz	Herzog	Sattel
FORM	Kabel	Kabeljau	Promille
FORM	Kamera	Kamerad	Teilung
FORM	Klima	Klimax	Arznei
FORM	Koloss	Kolosseum	Schirmung
FORM	Kram	Krampf	Spinat
FORM	Kuli	Kulisse	Nahrung
FORM	Mond	mondän	kehlig
FORM	nett	netto	Tabak
FORM	Prinz	Prinzip	Beitrag
FORM	Profi	Profil	Lesung
FORM	Qual	Qualm	Tiger
FORM	Schal	Schall	Marder
FORM	Scham	Schamott	Näpfchen
FORM	Schar	scharf	Handel
FORM	schau	Schaum	Legion
FORM	Schlaf	schlaff	reisend
FORM	schlau	Schlauch	Weibchen

FORM	schmal	Schmalz	Ausweis
FORM	Schwan	Schwanz	Tabelle
FORM	Sehne	Sehnerv	Windung
FORM	Sprit	Spritze	Klammer
FORM	Stau	Staub	Faden
FORM	Stil	Still	Klage
FORM	Vati	Vatikan	Plastik
OPAQUE	Beton	Betonung	Pflaster
OPAQUE	Bett	Bettler	Scharte
OPAQUE	Bild	Bildung	Fenster
OPAQUE	Brei	Breit	spitz
OPAQUE	Dach	Dachs	Welpe
OPAQUE	dich	dicht	ausen
OPAQUE	Diplom	Diplomat	Erlebnis
OPAQUE	Direkt	Direktor	Stimmung
OPAQUE	Fass	Fassung	Kellner
OPAQUE	Fluch	Flucht	Tagung
OPAQUE	Gabel	Gabelung	Pfuscher
OPAQUE	Heft	Heftig	prompt
OPAQUE	Muff	Muffel	Schote
OPAQUE	Müll	Müller	Garage
OPAQUE	Schach	Schachtel	Reflexion
OPAQUE	Schaf	Schaft	Orakel
OPAQUE	Scheck	scheckig	zellular
OPAQUE	Scheu	Scheusal	Vanillin

OPAQUE	Schick	Schicksal	Abteilung
OPAQUE	Schlag	Schlager	Elektron
OPAQUE	Schrein	Schreiner	Blaubeere
OPAQUE	Schuss	Schussel	Argernis
OPAQUE	Schweiß	Schweißer	Gleichnis
OPAQUE	Spieß	Spießer	Aderung
OPAQUE	Spinne	Spinner	Besteck
OPAQUE	Stift	Stiftung	Exemplar
OPAQUE	Tablett	Tablette	Liedchen
OPAQUE	Trakt	Traktor	Respekt
OPAQUE	Zeit	Zeitung	Polizei
OPAQUE	Zeug	Zeugung	Schakal
TRANSPARENT	Abend	Abends	danach
TRANSPARENT	Breit	Breite	Redner
TRANSPARENT	Dampf	Dampfer	Öffnung
TRANSPARENT	Dreck	dreckig	visuell
TRANSPARENT	Fisch	Fischer	Teilung
TRANSPARENT	Folter	Folterung	Aufhänger
TRANSPARENT	Fracht	Frachter	Schulung
TRANSPARENT	Frucht	fruchtig	verrucht
TRANSPARENT	Geiz	geizig	fügsam
TRANSPARENT	Gesell	gesellen	empörend
TRANSPARENT	Gewinn	Gewinner	Starkung
TRANSPARENT	Kies	Kiesel	Grille
TRANSPARENT	Kleid	Kleidung	Teilchen

TRANSPARENT	Koch	Kocher	Hündin
TRANSPARENT	krank	Kranke	Saison
TRANSPARENT	Leer	Leere	Brett
TRANSPARENT	Licht	Lichtung	Streuner
TRANSPARENT	Mehl	mehlig	spröde
TRANSPARENT	Rauch	Raucher	Diamant
TRANSPARENT	Rezept	Rezeptur	Kopplung
TRANSPARENT	Schiff	Schiffer	Mutation
TRANSPARENT	Spalt	Spaltung	Verdacht
TRANSPARENT	Steig	Steiger	Besteck
TRANSPARENT	Strahl	Strahlung	Rücksicht
TRANSPARENT	Streit	Streiter	Brechung
TRANSPARENT	Streng	Strenge	Kreisel
TRANSPARENT	Treu	Treue	Paket
TRANSPARENT	Urlaub	Urlauber	Aggregat
TRANSPARENT	Wirr	Wirrsal	Zyniker
TRANSPARENT	Zauber	Zauberer	Schlucht

Appendix 5: Stimuli Experiments 5 and 6

Condition	**Target**	**Related Prime**	**Unrelated Prime**
FORM LOW	auto	autopsy	barrack
FORM LOW	basil	basilica	executor
FORM LOW	blur	blurb	mince
FORM LOW	buff	buffet	tetanus
FORM LOW	camel	camellia	lollipop
FORM LOW	chase	chaste	blotch
FORM LOW	chat	chateau	discord
FORM LOW	chime	chimera	abreast
FORM LOW	chin	chintz	adduct
FORM LOW	counter	counterfeit	malevolence
FORM LOW	curl	curlew	breech
FORM LOW	flame	flamenco	conveyor
FORM LOW	grove	grovel	cosmos
FORM LOW	hero	heron	bliss
FORM LOW	limp	limpid	broach
FORM LOW	mild	mildew	crutch
FORM LOW	polar	polaroid	hyacinth
FORM LOW	bike	bikini	allele
FORM LOW	salmon	salmonella	centrifuge
FORM LOW	salt	saltire	rivulet
FORM LOW	span	spank	affix
FORM LOW	spin	spinach	leprosy
FORM LOW	stir	stirrup	aerosol

FORM LOW	sultan	sultana	bassoon
FORM LOW	tomb	tombola	apricot
FORM LOW	trap	trapeze	acronym
FORM LOW	trip	tripod	yogurt
FORM LOW	twin	twinge	cocoon
FORM LOW	unto	untold	ablaze
FORM LOW	virtue	virtuoso	achilles
FORM MEDIUM	advent	adventurer	dedication
FORM MEDIUM	cart	cartoon	analyst
FORM MEDIUM	coin	coincide	disclose
FORM MEDIUM	dial	dialect	boycott
FORM MEDIUM	diploma	diplomatic	chromosome
FORM MEDIUM	diver	diverge	forfeit
FORM MEDIUM	feat	feather	anguish
FORM MEDIUM	flan	flank	beech
FORM MEDIUM	fort	fortune	alcohol
FORM MEDIUM	gala	galaxy	accord
FORM MEDIUM	gall	gallop	insult
FORM MEDIUM	grave	gravel	matrix
FORM MEDIUM	grim	grimace	academy
FORM MEDIUM	harm	harmony	learner
FORM MEDIUM	lava	lavatory	registry
FORM MEDIUM	lure	lurch	boost
FORM MEDIUM	mate	maternal	acoustic
FORM MEDIUM	opera	operate	bizarre

FORM MEDIUM	parade	paradox	amateur
FORM MEDIUM	paste	pastel	monitor
FORM MEDIUM	pear	pearl	brick
FORM MEDIUM	pier	pierce	agenda
FORM MEDIUM	prose	prosecute	discharge
FORM MEDIUM	purse	pursue	attain
FORM MEDIUM	reside	residue	borough
FORM MEDIUM	scan	scandal	cocaine
FORM MEDIUM	scar	scarf	flinch
FORM MEDIUM	super	superior	discount
FORM MEDIUM	tram	tramp	flora
FORM MEDIUM	wren	wrench	ditch
FORM HIGH	belie	believe	support
FORM HIGH	bran	branch	impact
FORM HIGH	bride	bridge	aspect
FORM HIGH	brow	brown	guide
FORM HIGH	champ	champagne	paragraph
FORM HIGH	chap	chapter	manager
FORM HIGH	char	charge	effort
FORM HIGH	clot	clothes	foreign
FORM HIGH	comma	command	finance
FORM HIGH	confide	confident	knowledge
FORM HIGH	contra	contract	research
FORM HIGH	crow	crown	beach
FORM HIGH	deter	determine	similarly

FORM HIGH	disco	discover	continue
FORM HIGH	easter	eastern	billion
FORM HIGH	exam	example	benefit
FORM HIGH	gene	general	towards
FORM HIGH	gram	grammar	totally
FORM HIGH	mist	mistake	channel
FORM HIGH	plea	please	anyway
FORM HIGH	probe	problem	subject
FORM HIGH	prod	produce	develop
FORM HIGH	prom	promote	destroy
FORM HIGH	raisin	raising	stomach
FORM HIGH	sour	source	nature
FORM HIGH	surf	surface	account
FORM HIGH	thou	though	second
FORM HIGH	tong	tongue	breach
FORM HIGH	villa	village	concern
FORM HIGH	yell	yellow	attend

Condition	**Target**	**Related Prime**	**Unrelated Prime**
OPAQUE LOW	basal	basalt	hobbit
OPAQUE LOW	blaze	blazer	anchor
OPAQUE LOW	bounce	bouncer	adaptor
OPAQUE LOW	brisk	brisket	ringlet
OPAQUE LOW	buzz	buzzard	haggard
OPAQUE LOW	canvas	canvass	measles
OPAQUE LOW	coast	coaster	avenger

OPAQUE LOW	cramp	crampon	venison
OPAQUE LOW	aspire	aspirate	detonate
OPAQUE LOW	fabric	fabricate	affiliate
OPAQUE LOW	ginger	gingerly	expertly
OPAQUE LOW	hatch	hatchet	snippet
OPAQUE LOW	hawk	hawker	chaser
OPAQUE LOW	heath	heathen	abdomen
OPAQUE LOW	incur	incurable	printable
OPAQUE LOW	junk	junkie	collie
OPAQUE LOW	lever	leverage	blockage
OPAQUE LOW	linger	lingerie	bonhomie
OPAQUE LOW	liquid	liquidate	desecrate
OPAQUE LOW	locus	locust	sachet
OPAQUE LOW	overt	overture	insecure
OPAQUE LOW	poster	posterity	indignity
OPAQUE LOW	puff	puffin	vermin
OPAQUE LOW	steep	steeple	crackle
OPAQUE LOW	sting	stingy	brassy
OPAQUE LOW	stuff	stuffy	classy
OPAQUE LOW	treat	treatise	colonise
OPAQUE LOW	tune	tunic	lyric
OPAQUE LOW	vicar	vicarious	atrocious
OPAQUE LOW	victor	victorian	caucasian
OPAQUE MEDIUM	badge	badger	armour
OPAQUE MEDIUM	blank	blanket	leaflet

OPAQUE MEDIUM	bread	breadth	mammoth
OPAQUE MEDIUM	bullet	bulletin	restrain
OPAQUE MEDIUM	butch	butcher	cluster
OPAQUE MEDIUM	casual	casualty	vicinity
OPAQUE MEDIUM	chronic	chronicle	rationale
OPAQUE MEDIUM	chuck	chuckle	tremble
OPAQUE MEDIUM	colon	colonial	judicial
OPAQUE MEDIUM	compass	compassion	devolution
OPAQUE MEDIUM	crate	crater	bazaar
OPAQUE MEDIUM	crook	crooked	induced
OPAQUE MEDIUM	earn	earnest	longest
OPAQUE MEDIUM	feud	feudal	distal
OPAQUE MEDIUM	flee	fleet	chart
OPAQUE MEDIUM	flick	flicker	insider
OPAQUE MEDIUM	flour	flourish	childish
OPAQUE MEDIUM	gorge	gorgeous	rigorous
OPAQUE MEDIUM	helm	helmet	packet
OPAQUE MEDIUM	hung	hungry	salary
OPAQUE MEDIUM	infant	infantry	cemetery
OPAQUE MEDIUM	monk	monkey	survey
OPAQUE MEDIUM	plane	planet	wicket
OPAQUE MEDIUM	recess	recession	companion
OPAQUE MEDIUM	spat	spatial	trivial
OPAQUE MEDIUM	surge	surgeon	auction
OPAQUE MEDIUM	tract	tractor	sponsor

OPAQUE MEDIUM	trait	traitor	settlor
OPAQUE MEDIUM	trick	trickle	console
OPAQUE MEDIUM	warrant	warranty	locality
OPAQUE HIGH	batt	battle	middle
OPAQUE HIGH	budge	budget	object
OPAQUE HIGH	candid	candidate	associate
OPAQUE HIGH	comb	combine	mention
OPAQUE HIGH	confer	conference	experience
OPAQUE HIGH	convent	convention	permission
OPAQUE HIGH	count	county	energy
OPAQUE HIGH	coup	couple	single
OPAQUE HIGH	depart	department	parliament
OPAQUE HIGH	discus*	discuss	serious
OPAQUE HIGH	earl	early	today
OPAQUE HIGH	forge	forget	affect
OPAQUE HIGH	germ	german	indian
OPAQUE HIGH	heave	heaven	oxygen
OPAQUE HIGH	matt	matter	worker
OPAQUE HIGH	mess	message	package
OPAQUE HIGH	moth	mother	answer
OPAQUE HIGH	avail	available	vegetable
OPAQUE HIGH	numb	number	either
OPAQUE HIGH	organ	organise	surprise
OPAQUE HIGH	toil	toilet	basket
OPAQUE HIGH	potent	potential	encourage

OPAQUE HIGH	proper	property	security
OPAQUE HIGH	quest	question	decision
OPAQUE HIGH	rout*	routine	decline
OPAQUE HIGH	sect	section	million
OPAQUE HIGH	sever	several	capital
OPAQUE HIGH	stab	stable	handle
OPAQUE HIGH	stead	steady	mostly
OPAQUE HIGH	stud	study	money

Condition	**Target**	**Related Prime**	**Unrelated Prime**
TRANSPARENT LOW	absent	absentee	pharisee
TRANSPARENT LOW	adapt	adapter	blocker
TRANSPARENT LOW	adjust	adjuster	convener
TRANSPARENT LOW	adverse	adversity	extremity
TRANSPARENT LOW	assert	assertive	impulsive
TRANSPARENT LOW	bleak	bleakly	crudely
TRANSPARENT LOW	blend	blender	emitter
TRANSPARENT LOW	cater	caterer	fiddler
TRANSPARENT LOW	chat	chatty	grumpy
TRANSPARENT LOW	cheek	cheekily	gloomily
TRANSPARENT LOW	coil	coiled	rutted
TRANSPARENT LOW	combat	combatant	meridian
TRANSPARENT LOW	comic	comical	abysmal
TRANSPARENT LOW	cream	creamy	flimsy
TRANSPARENT LOW	curd	curdle	bangle
TRANSPARENT LOW	deaf	deafen	madden
TRANSPARENT LOW	drunk	drunkard	pilchard
TRANSPARENT LOW	grain	grainy	choosy
TRANSPARENT LOW	grasp	grasping	bottling
TRANSPARENT LOW	hostel	hostelry	artistry
TRANSPARENT LOW	idiot	idiotic	nomadic
TRANSPARENT LOW	inhibit	inhibitor	oppressor
TRANSPARENT LOW	kneel	kneeling	blurring
TRANSPARENT LOW	lamb	lambing	beaming

TRANSPARENT LOW	lemon	lemonade	blockade
TRANSPARENT LOW	marsh	marshy	bouncy
TRANSPARENT LOW	moan	moaning	welding
TRANSPARENT LOW	spoil	spoilt	deceit
TRANSPARENT LOW	urine	urinate	deflate
TRANSPARENT LOW	widow	widower	boarder
TRANSPARENT MEDIUM	advise	advisory	category
TRANSPARENT MEDIUM	betray	betrayal	pastoral
TRANSPARENT MEDIUM	bitter	bitterly	annually
TRANSPARENT MEDIUM	bless	blessing	knitting
TRANSPARENT MEDIUM	detect	detection	communion
TRANSPARENT MEDIUM	borrow	borrowing	lingering
TRANSPARENT MEDIUM	chemist	chemistry	jewellery
TRANSPARENT MEDIUM	clinic	clinical	imperial
TRANSPARENT MEDIUM	confess	confession	adaptation
TRANSPARENT MEDIUM	defend	defender	attacker
TRANSPARENT MEDIUM	drain	drainage	shortage
TRANSPARENT MEDIUM	dwell	dwelling	planting
TRANSPARENT MEDIUM	emotion	emotional	classical
TRANSPARENT MEDIUM	execute	execution	dimension
TRANSPARENT MEDIUM	favour	favourite	composite
TRANSPARENT MEDIUM	fragile	fragility	deformity
TRANSPARENT MEDIUM	frighten	frightening	surrounding
TRANSPARENT MEDIUM	gloom	gloomy	binary
TRANSPARENT MEDIUM	graph	graphics	nowadays

TRANSPARENT MEDIUM	hunt	hunting	farming
TRANSPARENT MEDIUM	inject	injection	exclusion
TRANSPARENT MEDIUM	invent	invention	confusion
TRANSPARENT MEDIUM	invest	investor	surveyor
TRANSPARENT MEDIUM	logic	logical	illegal
TRANSPARENT MEDIUM	moist	moisture	treasure
TRANSPARENT MEDIUM	outrage	outrageous	disastrous
TRANSPARENT MEDIUM	penal	penalty	liberty
TRANSPARENT MEDIUM	slave	slavery	cavalry
TRANSPARENT MEDIUM	spell	spelling	grouping
TRANSPARENT MEDIUM	valid	validity	equality
TRANSPARENT HIGH	bound	boundary	ordinary
TRANSPARENT HIGH	cabin	cabinet	opinion
TRANSPARENT HIGH	chick	chicken	sixteen
TRANSPARENT HIGH	critic	critical	official
TRANSPARENT HIGH	locate	location	division
TRANSPARENT HIGH	custom	customer	laughter
TRANSPARENT HIGH	depress	depression	foundation
TRANSPARENT HIGH	differ	different	treatment
TRANSPARENT HIGH	edit	editor	mirror
TRANSPARENT HIGH	educate	education	provision
TRANSPARENT HIGH	elder	elderly	heavily
TRANSPARENT HIGH	elect	election	religion
TRANSPARENT HIGH	exact	exactly	clearly
TRANSPARENT HIGH	format	formation	extension

TRANSPARENT HIGH	historic	historical	industrial
TRANSPARENT HIGH	impress	impression	generation
TRANSPARENT HIGH	infect	infection	admission
TRANSPARENT HIGH	percent	percentage	discourage
TRANSPARENT HIGH	intellect	intellectual	circumstance
TRANSPARENT HIGH	medic	medical	liberal
TRANSPARENT HIGH	commit	commitment	management
TRANSPARENT HIGH	nerve	nervous	anxious
TRANSPARENT HIGH	norm	normal	appeal
TRANSPARENT HIGH	origin	original	material
TRANSPARENT HIGH	poet	poetry	luxury
TRANSPARENT HIGH	react	reaction	invasion
TRANSPARENT HIGH	sudden	suddenly	actually
TRANSPARENT HIGH	transact	transaction	supervision
TRANSPARENT HIGH	unite	united	marked
TRANSPARENT HIGH	weigh	weight	artist

Category	**Target**	**Related Prime**	**Unrelated Prime**
FORM NONWORD	gown	gownace	atomace
FORM NONWORD	wolf	wolfox	biasox
FORM NONWORD	bargain	bargainew	ceilingew
FORM NONWORD	laugh	laughod	choirod
FORM NONWORD	hover	hoverid	claspid
FORM NONWORD	rabbit	rabbitid	climaxid
FORM NONWORD	disturb	disturbow	concealow

FORM NONWORD	plight	plightew	cousinew
FORM NONWORD	faint	faintect	cruelect
FORM NONWORD	shed	shedose	curlose
FORM NONWORD	flock	flockir	demonir
FORM NONWORD	frown	frownil	dwellil
FORM NONWORD	scrap	scrapuce	fetchuce
FORM NONWORD	lawn	lawnue	goatue
FORM NONWORD	curb	curbace	gownace
FORM NONWORD	basin	basinete	griefete
FORM NONWORD	glow	glowil	harmil
FORM NONWORD	drip	dripose	jerkose
FORM NONWORD	gallon	gallonral	knightral
FORM NONWORD	riot	riotow	lambow
FORM NONWORD	herb	herbect	loafect
FORM NONWORD	agony	agonyil	orbitil
FORM NONWORD	onion	onionoid	pearloid
FORM NONWORD	wicket	wicketow	pencilow
FORM NONWORD	crust	crusta	quaila
FORM NONWORD	prank	prankop	questop
FORM NONWORD	anchor	anchorop	revoltop
FORM NONWORD	block	blockose	scentose
FORM NONWORD	bowel	bowelid	serumid
FORM NONWORD	clutch	clutchew	shieldew
FORM NONWORD	await	awaitau	slumpau
FORM NONWORD	depot	depotow	snackow

FORM NONWORD	catch	catchoon	sparkoon
FORM NONWORD	debut	debutuce	spoonuce
FORM NONWORD	cough	coughote	stainote
FORM NONWORD	oven	ovenony	suitony
FORM NONWORD	elbow	elbowop	sweatop
FORM NONWORD	choir	choirini	toastini
FORM NONWORD	palm	palmica	tombica
FORM NONWORD	jump	jumpow	yarnow

Condition	**Target**	**Related Prime**	**Unrelated Prime**
TRANSP NON-WORD	abolish	abolishal	contental
TRANSP NON-WORD	altar	altarer	idioter
TRANSP NON-WORD	bald	baldous	deafous
TRANSP NON-WORD	beast	beastage	stuckage
TRANSP NON-WORD	beef	beefal	dirtal
TRANSP NON-WORD	blast	blastize	lotusize
TRANSP NON-WORD	bunch	buncher	thumber
TRANSP NON-WORD	canon	canonion	brushion
TRANSP NON-WORD	caution	cautionable	depositable
TRANSP NON-WORD	cheat	cheation	drownion
TRANSP NON-WORD	coffin	coffiny	launchy
TRANSP NON-WORD	cousin	cousiner	regreter
TRANSP NON-WORD	drum	drumt	folkt
TRANSP NON-WORD	dwarf	dwarfly	hauntly
TRANSP NON-WORD	erupt	erupter	fueller

TRANSP NON-WORD	feast	feasten	treaden
TRANSP NON-WORD	fist	fistion	soapion
TRANSP NON-WORD	foam	foamly	mythly
TRANSP NON-WORD	guild	guildy	shawly
TRANSP NON-WORD	haul	haulial	mildial
TRANSP NON-WORD	hazard	hazardal	pigeonal
TRANSP NON-WORD	hurl	hurlion	plotion
TRANSP NON-WORD	insect	insectal	accordal
TRANSP NON-WORD	knot	knotor	gaspor
TRANSP NON-WORD	loop	loopine	emitine
TRANSP NON-WORD	pond	pondal	gulfal
TRANSP NON-WORD	pouch	pouchion	shrubion
TRANSP NON-WORD	repeat	repeatal	switchal
TRANSP NON-WORD	request	requesty	adjourny
TRANSP NON-WORD	shark	sharky	yachty
TRANSP NON-WORD	silk	silker	dualer
TRANSP NON-WORD	stem	stemet	gridet
TRANSP NON-WORD	trench	trenchion	carrotion
TRANSP NON-WORD	turf	turfit	plugit
TRANSP NON-WORD	twist	twistly	prawnly
TRANSP NON-WORD	vapour	vapourer	bulleter
TRANSP NON-WORD	veil	veily	trapy
TRANSP NON-WORD	waist	waistle	strawle
TRANSP NON-WORD	wisdom	wisdomly	colourly
TRANSP NON-WORD	wrist	wristion	sewerion

Appendix 6

The Twelve Bilingual Dominance Scale Questions (Dunn & Fox Tree, 2009)

Questions 1 & 2:

At what age did you first learn German ________

English ________?

Scoring: 0-5 yrs = +5, 6-9 yrs = +3, 10-15 yrs = +1, 16 and up = +0

Questions 3 & 4:

At what age did you feel comfortable speaking this language? (If you still do not feel comfortable, please write "not yet.")

German ________

English ________

Scoring: 0-5 yrs = +5, 6-9 yrs = +3, 10-15 yrs = +1, 16 and up = +0, "not yet" = +0

Question 5:

Which language do you predominately use at home?

German ________

English ________

Both ________

Scoring: if one language used at home, +5 for that language; if both used at home, +3 for each language

Question 6:

When doing math in your head (such as multiplying 243 x 5), which language do you calculate the numbers in? ________________

Scoring: +3 for language used for math; +0 if both

Question 7:

If you have a foreign accent, which language(s) is it in? ________________

Scoring: If one language is listed, add +5 to the opposite language of the one listed. If both languages are listed, add +3 to both languages. If no language is listed, add nothing.

Question 8:

If you had to choose which language to use for the rest of your life, which language would it be? ____________________

Scoring: +2 for language chosen for retention

Questions 9 & 10:

How many years of schooling (primary school through university) did you have in:

German ________

English ________

Scoring: 1-6 yrs = +1, 7 and more yrs = +2

Question 11:

Do you feel that you have lost any fluency in a particular language? ________

If yes, which one? ________ At what age? ________

Scoring: -3 in language with fluency loss; -0 if neither has lost fluency

Question 12:

What country/region do you currently live in? _________________

Scoring: +4 for predominant language of country/region of residence

Appendix 7

The Revised Bilingual Dominance Scale

Question 1

At what age did you first learn German ___________

English ___________?

(Indicate 0 for the language(s) you spoke at home when growing up).

Scoring: 0-5 yrs = +5, 6-9 yrs = +3, 10-15 yrs = +1, 16 and up = +0

Question 2

At what age did you feel comfortable speaking the following languages:

(Indicate 0 for language(s) you spoke at home; if you still do not feel comfortable with either language, please write 'not yet')

German ____________

English ____________

Scoring: 0-5 yrs = +5, 6-9 yrs = +3, 10-15 yrs = +1, 16 and up = +0

Question 3

3a) At present, which language do you predominantly speak with members of your family?

Family member	***Language***
(if you speak a different language with different member of your family, please list each separately; if you speak only one language, please list only one language for the entire family)	
e.g. family	e.g. German
or	
e.g. mum	e.g. English
e.g. dad	e.g. German
______________________	_______________
______________________	_______________
______________________	_______________
______________________	_______________

3b) At present, which language do you predominantly use for studying/ at work?

____

Scoring: if one language used at home, +5 for that language; if both used at home, +3 for each language; add +3 for language used at work

Question 4 (Scoring: +3 for language used for math; +0 if both)

When doing math in your head (such as multiplying 243 x 5), which language do you calculate the numbers in?

____

Question 5

Do you have a noticeable **foreign, non-native** accent in English? Yes ☐ No ☐

Scoring: If one language is listed, add +5 to the opposite language of the one listed. If both languages are listed, add +3 to both languages. If no language is listed, add nothing.

Question 6

If you could choose between using German and English in certain situations, which language would you feel more comfortable using when

Talking to friend	English ☐	German ☐
Giving presentations about your work/ studies	English ☐	German ☐
Speaking to a stranger on the phone	English ☐	German ☐

Scoring: add +3 for each language selected; add 0 is both are selected

Question 7

How many years of education (primary through to university) did you spend in a **purely**

German speaking ________________ learning environment?

English speaking ________________ learning environment?

Scoring: 1-6 yrs = +1, 7 and more yrs = +2

Question 8

How many months or years have you lived in a

German speaking country _________________?

English speaking country __________________?

(Please note that this includes any time you lived in a particular country that was not for holiday purposes, but includes any time spent for studying, working, etc.)

Scoring: 1-6 yrs = +1, 7 and more yrs = +2

Question 9

Do you feel you have lost any fluency (e.g. you are struggling to find words, your sentence structure is not quite correct) in a particular language?

If yes, please indicate whether this applies to either German or English or both:

____

At what age did you lose fluency? _______

Scoring: -3 in language with fluency loss; -0 if neither has lost fluency

Question 10

Where do you currently live (at the time of the experiment)? Please indicate country:

____________________.

Scoring: +4 for predominant language of country/region of residence

Appendix 8

English Word	German Translation	English Word	German Translation
arch		liquid	
bamboo		marsh	
basil		moth	
blur		pluck	
butt		plum	
chance		secret	
counter		snip	
crow		sting	
deter		string	
dial		stuff	
drive		supple	
enter		trait	
force		treat	
forest		whisk	
free		alien	
germ		beef	
heart		combat	
infer		defend	
opera		defer	
pier		diet	
place		dream	
plain		employ	
quart		enjoy	
salmon		evict	
since		filth	
sombre		flesh	
stir		fluff	
tomb		froth	
trap		gloom	
wren		green	
adult		guard	
barb		guilt	
both		humid	
buzz		insist	
candid		knock	
casual		mourn	
coast		myth	
count		preach	
earl		quiet	
feud		self	
fleet		splash	

flour		steam	
gloss		wealth	
infant		widow	
invent		iron	

Appendix 9

German Word	English Translation	German Word	English Translation
Affe		**Gabelung**	
Alge		**Heftig**	
Blei		**Muffel**	
flau		**Müller**	
Geste		**Schachtel**	
Herz		**Schaft**	
Kabel		**scheckig**	
Kamera		**Scheusal**	
Klima		**Schicksal**	
Koloss		**Schlager**	
Kram		**Schreiner**	
Kuli		**Schussel**	
Mond		**Schweißer**	
nett		**Spießer**	
Prinz		**Spinner**	
Profi		**Stiftung**	
Qual		**Tablette**	
Schal		**Traktor**	
Scham		**Zeitung**	
Schar		**Zeugung**	
schau		**Abend**	
Schlaf		**Breit**	
schlau		**Dampf**	
schmal		**Dreck**	
Schwan		**Fisch**	
Sehne		**Folter**	
Sprit		**Fracht**	
Stau		**Frucht**	
Stil		**Geiz**	
Vati		**Gesell**	
Betonung		**Gewinn**	
Bettler		**Kies**	
Bildung		**Kleid**	
Breit		**Koch**	
Dachs		**krank**	
dicht		**Leer**	
Diplomat		**Licht**	
Direktor		**Mehl**	
Fassung		**Rauch**	
Flucht		**Rezept**	

Schiff		**Streng**	
Spalt		**Treu**	
Steig		**Urlaub**	
Strahl		**Wirr**	
Streit		**Zauber**	

Appendix 10

Word	Y	N	Word	Y	N	Word	Y	N	Word	Y	N		Y	N
autopsy			barack			object			confusion			discuss		
abolishal			executor			meridian			surveyor			early		
blurb			mince			experience			illegal			suitony		
buffete			tetanus			parliament			treasure			german		
baldous			altarer			scrapuce			disastrous			heaven		
chaste			blotch			section			liberty			matter		
chateau			discord			county			slumpau			sweatop		
chimera			beastage			curbace			grouping			mother		
chintz			adduct			forget			equality			available		
counterfeit			blastize			basinete			ordinary			number		
curlew			breech			either			official			tombica		
beefal			conveyor			glowil			division			toilet		
grovel			buncher			dripose			curlose			potential		
heron			bliss			message			foundation			yarnow		
canonion			broach			surprise			treatment			question		
mildew			crutch			lawnue			mirror			religion		
polaroid			hyacinth			package			serumid			serious		
cautionable			cheation			gallonral			binary			today		
salmonella			centrifuge			mostly			nowadays			affect		
saltire			rivulet			property			farming			indian		
coffiny			affix			convener			exclusion			oxygen		
spinach			leprosy			study			spelling			worker		
stirrup			cousiner			knightral			validity			snackow		
drumt			bassoon			reaction			boundary			answer		
tombola			apricot			education			cabinet			vegetable		
dwarfly			acronym			artist			shieldew			organise		
tripod			yogurt			riotow			critical			sparkoon		
feasten			cocoon			marked			location			basket		
untold			ablaze			nervous			customer			encourage		
virtuoso			erupter			luxury			depression			security		
fistion			dedication			herbect			different			decision		
cartoon			analyst			anxious			editor			heavily		
coincide			foamly			impression			imperial			ringlet		
dialect			boycott			emitter			debutuce			plightew		
diplomatic			turfit			fiddler			attacker			bouncer		
diverge			forfeit			bangle			shortage			griefete		
twistly			vapourer			choirod			planting			elderly		
flank			beech			blurring			classical			election		
veily			alcohol			drunkard			questop			exactly		
galaxy			waistle			ceilingew			composite			formation		
gallop			insult			idiotic			invention			historical		
wisdomly			matrix			artistry			investor			gownace		
grimace			academy			biasox			logical			infection		
harmony			wristion			blockade			moisture			percentage		
lavatory			registry			choirini			outrageous			intellectual		
lurch			boost			lemonade			penalty			medical		
idioter			acoustic			elbowop			slavery			commitment		
operate			bizarre			urinate			cruelect			provision		
paradox			amateur			prankop			sixteen			handle		
mythly			shawly			betrayal			hostelry			agonyil		
pearl			brick			annually			ovenony			money		
pierce			folkt			lingering			inhibitor			pharisee		
hauntly			discharge			anchorop			chemistry			blocker		
pursue			attain			dimension			clinical			onionoid		
residue			soapion			blockose			confession			extremity		
scandal			cocaine			surrounding			defender			impulsive		
scarf			flinch			bowelid			revoltop			harmil		
superior			discount			drainage			dwelling			normal		
mildial			flora			opinion			emotional			original		
wrench			ditch			clutchew			execution			poetry		
irish			pigeonal			chicken			favourite			fetchuce		
branch			impact			laughter			scentose			suddenly		
plotion			aspect			fragility			frightening			transaction		

brown			guide			awaitau			gloomy			jerkose		
champagne			fueller			cavalry			graphics			battle		
chapter			manager			depotow			hunting			budget		
charge			effort			adaptation			injection			candidate		
clothes			accordal			borrowing			claspid			combine		
command			finance			sharky			nomadic			conference		
treaden			knowledge			basilica			oppressor			convention		
contract			research			requesty			jumpow			toastini		
crown			gaspor			lollipop			beaming			couple		
determine			similarly			camellia			cousinew			department		
discover			continue			abreast			bouncy			middle		
trapy			billion			repeatal			welding			spoonuce		
example			strawle			flamenco			deceit			associate		
prawnly			towards			pouchion			deflate			mention		
grammar			totally			cosmos			loafect			flockir		
mistake			plugit			pondal			category			permission		
please			anyway			malevolence			pastoral			energy		
bulleter			subject			haulial			pencilow			single		
produce			carrotion			allele			knitting			frownil		
gridet			destroy			guildy			communion			nature		
raising			stomach			spank			quaila			bargainew		
source			dualer			hazardal			deformity			second		
surface			account			limpid			actually			hoverid		
though			yachty			disclose			supervision			village		
tongue			breach			twinge			lambow			rabbitid		
adjourny			concern			bikini			kneeling			basalt		
yellow			attend			hurlion			lambing			hobbit		
colourly			sewerion			sultana			concealow			disturbow		
blazer			anchor			aerosol			marshy			crusta		
gownace			adaptor			adventurer			moaning			absentee		
brisket			wolfox			trapeze			spoilt			adapter		
buzzard			haggard			insectal			pearloid			adjuster		
canvass			measles			achilles			widower			adversity		
coaster			avenger			knotor			advisory			assertive		
crampon			venison			chromosome			orbitil			decline		
loopine			bitterly			aspirate			detonate			million		
anguish			blessing			fabricate			affiliate			capital		
silker			detection			gingerly			expertly			hungry		
feather			coughote			hatchet			snippet			infantry		
fortune			jewellery			hawker			chaser			monkey		
stemet			bleakly			heathen			abdomen			planet		
accord			blender			incurable			printable			recession		
trenchion			caterer			junkie			collie			spatial		
gravel			palmica			leverage			blockage			surgeon		
contental			bonhomie			lingerie			cheekily			tractor		
boarder			desecrate			liquidate			coiled			traitor		
learner			sachet			locust			combatan			trickle		
united			insecure			overture			comical			warranty		
weight			indignity			posterity			creamy			salary		
puffin			vermin			maternal			curdle			cemetery		
steeple			crackle			emitine			deafen			survey		
stingy			brassy			gulfal			climaxid			wicket		
stuffy			classy			monitor			grainy			companion		
treatise			colonise			launchy			grasping			trivial		
tunic			lyric			generation			crudely			auction		
vicarious			atrocious			prosecute			wicketow			sponsor		
victorian			caucasian			drownion			chatty			settlor		
badger			armour			tramp			grumpy			console		
blanket			leaflet			depositable			gloomily			locality		
breadth			mammoth			borough			rutted			develop		
bulletin			restrain			brushion			catchoon			eastern		
butcher			cluster			agenda			abysmal			switchal		
casualty			vicinity			regreter			flimsy			general		
chronicle			rationale			pastel			atomace			faintect		
chuckle			tremble			thumber			madden			shedose		
colonial			judicial			below			pilchard			benefit		
compassion			devolution			lotusize			choosy			channel		

crater			bazaar			bridge			bottling			laughod		
crooked			induced			dirtal			clearly			problem		
earnest			longest			paragraph			extension			promote		
feudal			distal			stuckage			industrial			management		
fleet			chart			foreign			demonir			dwellil		
flicker			insider			confident			admission			appeal		
flourish			childish			deafous			discourage			material		
gorgeous			rigorous			beach			circumstance			goatue		
helmet			packet			shrubion			liberal			invasion		
stainote			steady			several			stable			routine		