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REVISITING LEXICAL AMBIGUITY EFFECTS IN VISUAL WORD RECOGNITION

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“Siamo stanchi di diventare giovani seri, o contenti per forza, o criminali, o nevrotici: vogliamo ridere, essere innocenti, aspettare qualcosa dalla vita, chiedere, ignorare. Non vogliamo essere subito così sicuri. Non vogliamo essere subito già così senza sogni.”

Pier Paolo Pasolini

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Salerno, 22 gennaio 2014 *Sinceramente, A.*

REVISITING LEXICAL AMBIGUITY EFFECTS IN VISUAL WORD RECOGNITION

Chapter 5: The role of the "context" in lexical processing of homonyms:

Chapter 6: A glance at polysemy: sense effects in word recognition


SCRATCH
MAYBE I'LL START WITH THE ACKNOWLEDGEMENTS...
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PREFAZIONE

L'argomento principale di questo lavoro è lo studio del modo in cui le forme lessicalmente ambigue di una lingua siano rappresentate all'interno del lessico mentale dei parlanti.

L'esistenza di parole che veicolano significati e/o sensi multipli (ad esempio, *credenza, mora*, ecc.) è una caratteristica propria del linguaggio naturale. I parlanti della maggior parte delle lingue esistenti si imbattono quotidianamente in parole ambigue dal punto di vista lessicale, la cui corretta interpretazione avviene principalmente mediante il ricorso al contesto linguistico in cui tali forme sono inserite. Nel Capitolo 1, fornirò una prima definizione del concetto di ambiguità del linguaggio, attraverso un'analisi dei diversi livelli linguistici ai quali occorrono casi di ambiguità e del modo in cui il fenomeno venga gestito nelle interazioni quotidiane tra i parlanti.

Nel Capitolo 2, presenterò una rassegna dei principali studi condotti in ambito linguistico, psicolinguistico e neuropsicologico che hanno indagato il modo in cui avvengano i processi di risoluzione dell'ambiguità in contesto. La capacità dei nostri sistemi di elaborazione di comprendere e disambiguare frasi contenenti forme ambigue in maniera tanto veloce da non rendercene nemmeno conto è la testimonianza di quanto siano sofisticate le competenze linguistiche in nostro possesso. Il tentativo di fornire una spiegazione adeguata dei processi che sottostanno alla comprensione di forme ambigue ha da sempre affascinato gli studiosi di linguaggio. In particolare, l'influenza esercitata dal contesto sui processi di disambiguazione è stato uno dei temi che i ricercatori hanno maggiormente indagato.

Un'altra questione relativa alle modalità di elaborazione delle forme ambigue è stata per anni al centro del dibattito e tuttora rimane piuttosto controversa: il fatto di veicolare significati multipli potrebbe determinare differenze nelle modalità di rappresentazione lessicale e nei conseguenti processi di elaborazione rispetto a parole dal significato univoco? Nel Capitolo 3, viene fornita una rassegna ragionata dei principali studi che hanno comparato l'elaborazione delle forme ambigue con quella delle forme non ambigue in prove di riconoscimento delle forme scritte presentate in isolamento. In numerosi studi, a partire dalle ricerche pioneristiche di Rubenstein e collaboratori (1970; 1971), si riscontra un effetto di facilitazione (*ambiguity advantage effect*) sulle forme omonime (tempi di reazione più veloci in un compito di decisione lessicale visiva). Tuttavia, l'esistenza di differenze di elaborazione tra forme ambigue e forme non ambigue è tutt'oggi oggetto di un acceso dibattito; i dati sperimentali sono altamente disomogenei (in altri studi si riscontra un'assenza di effetto o, addirittura, un effetto di *ambiguity disadvantage*). In particolare, discuterò le discordanze empiriche riportate in letteratura alla luce delle differenze metodologiche rinvenute tra gli studi condotti.

Con il presente lavoro di ricerca si intende contribuire al dibattito esistente in letteratura circa le modalità di elaborazione/rappresentazione delle forme ambigue, cercando di dettagliare quanto più possibile come avvenga l'accesso lessicale alle rappresentazioni multiple veicolate da tali forme e quali siano i fattori in grado di influenzarne l'elaborazione. Anzitutto, negli studi condotti si è cercato di indagare separatamente forme omonimiche (veicolanti significati tra loro non connessi) e forme polisemiche (veicolanti sensi tra loro collegati dal punto di vista semantico e/o etimologico). L'ipotesi di partenza è che tale distinzione non sia puramente formale, bensì che i processi di elaborazione implicati siano differenti, dal momento che è la stessa natura delle rappresentazioni semantiche veicolate a subire delle variazioni (si va da un grado più o meno elevato di condivisione dei tratti semantici nelle forme polisemiche ad una distinzione più o meno netta delle rappresentazioni semantiche veicolate nel caso delle forme omonimiche). In secondo luogo, gli studi condotti hanno avuto come obiettivo quello di indagare quali siano i fattori in grado di influenzare - a livello specificamente lessicale - le modalità di elaborazione delle forme ambigue. In particolare, si è tentato di dar conto di diverse variabili, allo scopo di comprenderne l'interazione con l'elaborazione delle forme ambigue:

- ✓ la categoria grammaticale di appartenenza delle forme ambigue (stessa classe, ad es. *credenza* vs. classe differente, ad es. *bucato*);
- ✓ la frequenza relativa dei significati veicolati (bilanciati, ad es. *costa* vs. non bilanciati, ad es. *campione*).
- ✓ la classe flessiva di appartenenza delle forme ambigue (stessa classe, ad es. *lavanda* vs. classe differente, ad es. *conte*).

Mediante la manipolazione di tali variabili sono state ottenute diverse tipologie di forme ambigue, la cui elaborazione è stata comparata a quella di parole non ambigue in compiti di riconoscimento visivo.

Nel Capitolo 4, mi soffermerò sull'elaborazione di forme omonimiche dell'italiano presentate in isolamento. In particolare, illustrerò i risultati di quattro esperimenti in cui le diverse tipologie di omonimi sono indagate e presenterò un modello di accesso lessicale in grado di dar conto dei differenti effetti di ambiguità riportati.

Nel Capitolo 5, presenterò i risultati di quattro esperimenti condotti con paradigma di priming semantico e morfologico sulle stesse forme omonimiche utilizzate in precedenza. In particolare, discuterò gli effetti di modulazione della facilitazione semantica e morfologica alla luce dell'influenza esercitata dalla classe grammaticale di appartenenza e dal rapporto di frequenza delle forme lessicalmente ambigue.

Il Capitolo 6 è dedicato interamente allo studio delle modalità di elaborazione/rappresentazione delle forme polisemiche dell'italiano. I differenti effetti di polisemia riportati saranno discussi alla luce del modello di accesso lessicale presentato e delle predizioni riguardanti le differenze di rappresentazione rispetto alle forme omonimiche.

Nel capitolo 7, mi soffermerò sull'implementazione di un modello computazionale basato su una semplice rete neurale addestrata in maniera supervisionata e descriverò i risultati simulativi in chiave comparativa rispetto ai dati comportamentali ottenuti sulle forme omonimiche.

Nell'insieme, i dati sembrerebbero dimostrare come l'ambiguità lessicale non sia un fenomeno omogeneo, per cui non abbia senso parlare di generici effetti di "vantaggio" o "svantaggio" dell'ambiguità. A livello specificamente lessicale, intervengono una serie di fattori in grado di influenzare le modalità di elaborazione delle forme ambigue.

In secondo luogo, i dati ottenuti sono in linea con alcune delle assunzioni più generali circa il ruolo svolto da alcuni fattori lessicali e morfologici (quali la classe grammaticale, la frequenza, la classe flessiva, ecc.) nell'elaborazione linguistica, inserendosi a pieno titolo nella ricerca sull'organizzazione e il funzionamento del sistema lessicale. Studi di questo genere permettono infatti di fornire risposte a importanti domande circa il funzionamento dei processi lessicali di produzione e comprensione. In particolare, i risultati sperimentali ottenuti hanno portato all'attenzione alcune variabili il cui ruolo non risulta esplicitamente specificato nei modelli di accesso lessicale.

FOREWORD

The aim of this work is to focus on how lexically ambiguous words are represented in the mental lexicon of speakers.
The existence of words with multiple meanings/senses (e.g., *credenza, mora*, etc. in Italian) is a pervasive feature of natural language. Routinely speakers of almost all languages encounter ambiguous words, whose correct interpretation is made by recurring to the linguistic context in which these forms are inserted.
In Chapter 1, I will clarify the concept of language ambiguity, by describing all linguistic levels at which it can occur and how disambiguation processes are managed in human interactions.
In Chapter 2, I will provide a substantial overview of the most relevant linguistic, psycholinguistic and neuropsychological studies carried out over the last 40 years on lexical ambiguity resolution processes.
There is no doubt that cognitive and linguistic systems are extremely sophisticated to allow speakers to select the appropriate meaning and to solve any possible source of misunderstanding.
Anyway, the challenge of explaining how disambiguation processes exactly work provided a large impetus in the development of a great deal of experimental studies on the topic.

Most psycholinguistic studies prior to '90s have been focusing on the role played by context in disambiguating words with multiple meanings, namely, in assigning them an interpretation consistently with sentence context.

Another issue related to how ambiguous forms are processed has been a matter of debate: do ambiguous and unambiguous words differ in the basic principles underlying their lexical representation and processing? In Chapter 3, I will review the most relevant studies which investigated the lexical processing of ambiguous words presented out of context, in single word presentation tasks. The general aim of these works was to understand the impact of lexical ambiguity on word processing.

Many experiments comparing the processing of ambiguous and unambiguous words in isolation reported faster reaction times for ambiguous words than for unambiguous words in naming and visual lexical decision tasks; this effect is known as *ambiguity advantage effect* (*AAE*).

In spite of the great deal of investigations over the past 40 years, the existence of processing differences between ambiguous and unambiguous words is still extremely controversial. Many attempts to replicate the AAE failed to observe any effect or reported inhibitory effects (*ambiguity disadvantage effects*). Specifically, I will discuss the empirical discrepancies reported in literature on the topic by taking into account the methodological inconsistencies among studies.

The general aim of this research is to investigate the lexical processing/representation of ambiguous forms, by considering some variables which could play a role in accessing these words.

First of all, I will consider the ambiguity status of words, by distinguishing in the investigation forms with two distinct, unrelated meanings (namely, homonymous words) and forms with two distinct, but semantically and/or etymologically related senses (namely, polysemous words). Previous research, whether arguing for or against the existence of an ambiguity advantage effect in word recognition, has not systematically taken into consideration the semantic relatedness among meanings of ambiguous words. My hypothesis is that the homonymy/polysemy distinction is not merely formal, since it also involves different processing mechanisms, due

to the fact that these forms are differently stored in the mental lexicon. For instance, it seems reasonable to predict that polysemous words share a great deal of common semantic features, while homonymous words have distinct representations, each one for the specific meaning they can assume.
Secondly, the aim of my experiments is to verify if the recognition process of ambiguous words is affected by some variables which have not been taken into account in most previous works on the topic:

- ✓ the grammatical status of these forms, namely, whether there are processing differences between ambiguous forms belonging to the same grammatical class (e.g., *credenza*, which means both *faith* and *cupboard*) and grammatically ambiguous forms (nominal and verbal, e.g., *bucato*, which means both *laundry*, nominal meaning, and *punctured,* verbal meaning);
- ✓ the meaning frequency dominance, that is whether there are processing differences between balanced ambiguous words (two meanings which have equal probabilities of occurrence, e.g., *costa*, meaning both *coast* and *it costs*) and unbalanced ambiguous words (having a more frequent meaning, e.g., *campione*, meaning both *champion* and *sample*);
- ✓ the declensional class of ambiguous nouns, namely, whether there are processing differences between ambiguous nouns belonging to the same declensional class (e.g., *credenza*) and ambiguous nouns belonged to two different declensional classes (e.g., *teste*, which means both *heads* (-a/-e) and *witness* (-e/-i)).

By manipulating these variables, I obtained multiple subsets of experimental words, compared to unambiguous words in visual word recognition tasks.
In Chapter 4, the focus will be on the lexical processing of Italian homonymous words presented in isolation. Specifically, I will report and discuss the results of four experiments where the different typologies of homonyms are investigated; moreover, I will present a lexical access model to account for the different ambiguity effects reported.

In Chapter 5, I will report the results of four experiments involving both the semantic and the morphological priming paradigm, carried out on the same stimuli of the previous experiments. More in detail, I will discuss the modulation of priming effects by taking into account the role played by the grammatical class and the meaning frequency dominance.

The whole Chapter 6 will focus on the investigation of the lexical processing of polysemous words. The different polysemy effects reported will be discussed according to both the lexical access model presented and the predictions about the differences with homonymous words.

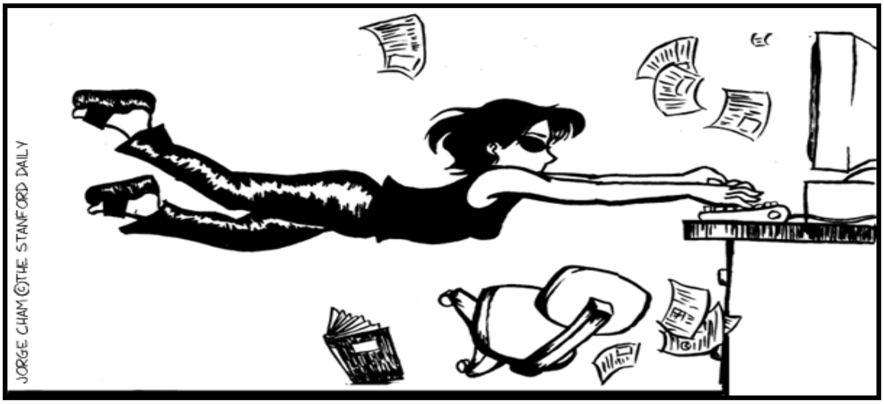
In Chapter 7, I will focus on the implementation of a computational model based on a simple neural network trained with a supervised algorithm. The simulation results will be compared to the behavioural results obtained on homonymous words.

All in all, the data of my research can be interpreted as an evidence that considering lexical ambiguity as a unique, homogeneous phenomenon could be improper, as it seems to be affected by many semantic, distributional and morphological variables. The idea is that the processing differences reported could reflect different lexical representations among categories of ambiguous items.

Secondly, the results shed light not only on lexical ambiguity effects but also on a more general assumption about which information levels are involved in word lexical access.

The different ambiguity effects depending on the grammatical class, the frequency dominance and the declensional class of ambiguous words provide evidence in favour of the idea that such abstract level information is represented in the input lexicon and necessarily accessed even though it is not explicitly required by the task.

In conclusion, these findings seem to show how it is crucial to assume a new methodological perspective in order to investigate the ambiguity effects in word recognition. Only by taking a broader view of the possible factors which could affect the lexical processing of ambiguous forms we will be able to direct our efforts more productively in order to understand the lexical ambiguity processing and its relation to other aspects of language processing.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CHAPTER 1

LANGUAGE AMBIGUITY:
DEFINITIONS AND LEVELS OF ANALYSIS

1.1 Introduction

Speakers of almost any language everyday deal with sentences and expressions which can be understood in two or more possible senses or ways. When we read something or we listen to someone speaking, we continuously give an interpretation to ambiguous materials, and this disambiguation process does not seem to be much of an issue in human communication; it is something that we handle effortlessly and unconsciously, in most of the cases. There is no doubt that cognitive and linguistic systems are extremely sophisticated to allow speakers succeed to select the appropriate meaning and solve any possible source of misunderstanding.
We tend to think of language as a clear and literal vehicle for accurately communicating ideas. But even when we use language literally, meanings shift, and some expressions can assume multiple nuances, figurative connotations and implied or hidden meanings. People can be intentionally or unintentionally ambiguous. Nevertheless, even when someone uses a potentially ambiguous sentence, usually listeners are extremely good at resolve the ambiguity recurring to context and their knowledge of the world.

Although ambiguity in language can be perceived as an obstacle for the mutual comprehension, actually language ambiguity provides value (Quiroga-Clare, 2003).

"Various people have said that ambiguity is a problem for communication. But once we understand that context disambiguates, then ambiguity is not a problem - it's something you can take advantage of, because you can reuse easy words in different contexts over and over again." (Piantadosi et al., 2012)

In a simplified and optimized model of how information is passed between a speaker and a listener, one could hypothesize that it could be better if each word has only one meaning to avoid any risk of misunderstanding and simplify the communication. Actually, this statement is wrong: it is cognitively cheaper if the listener does some conclusions from the conversation context, rather than the speaker has to spend more time on longer and more elaborate descriptions. The result is that a linguistic system that leans toward ambiguity by reusing the "easiest" words is the most desirable.

The same prediction could be made for language learning and storage processes: it seems more “economic” for our cognitive system to expand its range of meanings without having to continuously add new orthographic and phonological forms to its already long list of lexical items (Ahrens, 1998).

It results that “ambiguity is actually something you would want in the communication system", once the context is taken into account (Piantadosi et al., 2012).

Language is a very complex phenomenon. Meanings that can be taken for granted are in fact only the tip of a huge iceberg. Idiosyncratic, social and cultural backgrounds provide a moving ground on which those meanings take root and expand their branches. Studying how this linguistic phenomenon works represents a challenge for psycholinguistics researchers, who investigate how speakers use the information about words to communicate and how this linguistic knowledge is stored and accessed in the mental lexicon.

1.2 Language ambiguity: several levels of analysis

Ambiguity is a pervasive phenomenon in language which occurs at all levels of linguistic analysis. Out of context, words have multiple meanings, senses and/or grammatical classes, requiring speakers to determine which meaning and part of speech is intended.

Morphemes may also be ambiguous out of context, as in the English –s, which can denote either a plural noun marking (*trees*), a possessive (*Dylan's*), or a present tense verb conjugation (*runs*) (**morphological ambiguity**). Syllables are almost always ambiguous in isolation: they can be interpreted as providing incomplete information about the word the speaker is intending to communicate. Spoken language itself could be full of ambiguity, because listeners can segment it differently (e.g., the phonological fragment /ˈtjuːlɪps/ can be interpreted as two separate words, *two* and *lips*, or as one word, *tulips*) (**perceptual ambiguity**).

The most common type of linguistic ambiguity is **lexical ambiguity**, which belongs to single words and derives from the existence of homonymy and polysemy.

The word *homonymy* comes from the Greek ὁμώνυμος (*homonumos*), meaning “having the same name”, which is the conjunction of ὁμός (*homos*), “common” and ὄνομα (*onoma*), “name”. In other words, homonymy refers to two or more distinct concepts sharing the “same name”. **Homonymy** occurs when a lexical item accidentally carries two (or more) distinct and unrelated meanings. For example, the word *bank* can be used to denote either “a place where monetary exchange and handling takes place” or “the land close river”. Other examples of homonymy are everywhere. In fact, almost any word has more than one meaning:

"Note" = "A musical tone" or "A short written record."

"Lie" = "Statement that you know it is not true" or "present tense of lay: to be or put yourself in a flat position."

Homonymy also occurs when a word, which is not necessarily spelled the same but is pronounced the same, is used to have different meanings; we call it *homophony*. For example, the words *night* and *knight* are pronounced exactly the same although they are spelled differently, and they have very different meanings.

[1.1] It gets very cold here at night.

[1.2] The knight saved the princess.

Conversely, the word *tears* can be pronounced in two different ways and has two different meanings, respectively. This type of homonymy is called *homography.*

[1.3] Tears ran down his cheek.

[1.4] There are many tears in my jacket.

For languages with deep, opaque orthographies, like English, French or Arabic, where the relationship spell-pronounce is mainly irregular, the distinction between homography and homophony is crucial. At the contrary, for languages with shallow, transparent orthographies, like Spanish, Finnish or Italian, with their strict correspondence grapheme-phoneme rules and few exceptions, the dichotomy is not so helpful.

Polysemy (or polysemia) is a compound noun for a basic linguistic feature. The name comes from the Greek words πολυ-, *poly* (many) and σήμα, *sema* (to do with meaning, as in *semantics*). Polysemy is also called *radiation* or *multiplication*. This happens when a single lexical item acquires a wider range of different but related senses. For example, the word *paper* originally referred to writing material made from the papyrus reeds of the Nile, later to other writing materials, and now it refers to things such as government documents, scientific reports, family archives or newspapers. (Miller, 2001). Other examples of polysemy are:

The verb *to glare*

[1.5] The sun glared down from the hot desert sky.

[1.6] The angry girl glared at the boy who had pulled her hair.

The word *bright*

[1.7] The stars are bright tonight.

[1.8] She must be very bright if she made an "A" on the test.

There is a category, called "complementary polysemy" wherein a single verb has multiple senses, which are related to one another in some predictable way. An example is *bake*, which can be interpreted differently in different contexts:

[1.9] John baked the potato. (*change-of-state*)

[1.10] John baked a cake. (*creation*)

Also we can take the word "ambiguity" itself. It can mean an indecision as to what you mean, an intention to mean several things, a probability that one or other or both of two things has been meant, and the fact that a statement has several meanings.

Drawing the distinction between related and unrelated senses of a lexical form is often far from a straightforward matter. In a large number of cases, there is not an agreement among linguists and speakers as to whether the words are homonymous or polysemous. An example is the different meanings of the noun *head*, ‘part of the body’ and ‘leader of a group or company”. For some native English speakers, these senses may seem related, while others may not see any relation at all, because the linguistic contexts in which these words occur are extremely dissimilar.

At this point, the question is: what does it mean that two senses are related? The suggested criteria include etymology and speaker intuitions about unrelatedness vs. relatedness of meaning (Lyons , 1977b).

The first criterion is the etymological derivation of words. Words that are historically derived from the same lexical items are considered polysemous. On this approach, the noun *position*, which has the senses ‘a particular way in which someone or something is placed or arranged’ and ‘a person’s particular view or attitude toward something’, would be polysemous as a result of the shared etymological origin of its senses. According to the same criterion, the form *file* would be an instance of homonymy, as the sense ‘folder or box for holding loose papers’ originates from the French word *fil*, and the sense ‘tool with roughened surface(s)’ comes from the old English word *féol*. That these two senses came to be associated with the same lexical form in contemporary English is thus a matter of historical accident. However, this way of distinguishing between polysemy and homonymy is problematic. Firstly, for many words the historical derivation is uncertain; secondly, it is not always clear how far back we should go in tracing the history of words; thirdly, speakers may not be aware of the historical connections among words (Lyons, 1977).

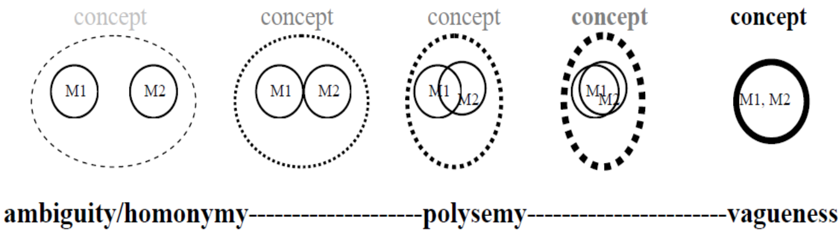

Figure 1.1 Homonymy, polysemy and vagueness on a continuum

The second criterion for the distinction between homonymy and polysemy is the ‘‘relatedness/unrelatedness of meaning”, as perceived by speakers. The distinction between homonymy and polysemy seems to correlate with the feelings of native speakers that some meanings are connected with each other while others not. (Klepousniotou, 2002). According to this criterion, two senses are polysemous if they are judged by native speakers to be related, and homonymous if they are judged to be unrelated. Distinguishing polysemy from homonymy would thus depend on a sort of ‘folk etymology’. However, it seems that ‘‘relatedness of meaning’’ is not an all-or-nothing relation, but rather a matter of degree. Finally, it seems that there is not a clear dichotomy between homonymy and polysemy, but rather a continuum from ‘‘pure’’ homonymy to ‘‘pure’’ polysemy (Lyons, 1977).

When the ambiguity is not in a single word, but between alternative syntactic structures underlying a sentence, the phenomenon is called **structural ambiguity**. Some examples of structural ambiguity:

[1.11] "John enjoys painting his models nude." Who is nude?

[1.12] "Visiting relatives can be so boring." Who is doing the visiting?

These ambiguities are said to be structural because each such phrase can be represented in two structurally different ways, e.g., 'John enjoys painting nude' and ‘His models are nude'. Indeed, the existence of such ambiguities provides strong evidence for a level of underlying syntactic structure.

In some case, ambiguity can have both a lexical and a structural basis, as with sentences like:

[1.13] “I left her behind for you”

[1.14] “He saw her duck”

Lexical ambiguity of words like *left* and *duck* produces sentences liable to have more than one interpretations.

Another famous example of structural ambiguity is the Italian expression:

[1.15] “la vecchia porta la sbarra”

meaning both “the old lady carries the bar” and “the old door blocks her”. Even in this case the structural ambiguity of the sentence comes from lexical ambiguity of words like *vecchia* (something old/old lady), *porta* (he, she carries/the door), *sbarra* (he,she blocks/the bar) (Tabossi, 2006).

Although ambiguity is fundamentally a property of linguistic expressions, people are also said to be ambiguous on occasion in how they use language. This can occur if their words do not make what they mean uniquely determinable, even when their words are unambiguous (Grice, 1989). Ambiguity in any substantial literary text indicates that the significance of the telling does not end with a single reading, and delivers to the reader a continuing effort of meaning-making.

In normal speech, ambiguity can sometimes be understood as something witty or deceitful. Actually, it should be extended to any verbal nuance, which gives room to alternative reactions to the same linguistic element. (**pragmatic ambiguity**).

The fact that ambiguity occurs at so many linguistic levels suggests that a far-reaching principle is needed to explain its origins and persistence. Linguists, philosophers of language and psychologists have long been interested in the ambiguity phenomenon due to the challenging issues it raises for theories of semantic representation, language processing and human communication.

1.3 Ambiguity and computational linguistics

Computational linguistics has two main aims: to enable computers to be used as aids in processing and translating natural language, and to investigate how speakers process language, by analogy with computers.
One of the most relevant challenge for this research field and especially for natural language processing (NPL) developers is the language ambiguity phenomenon. In fact, most ambiguities escape our notice because we are extremely good at resolving them using our knowledge of the world and contextual information. But computer systems do not have this knowledge, and consequently do not do a good job of disambiguating.
"Ambiguity is only good for us - as humans - because we have these really sophisticated cognitive mechanisms for disambiguating. It's really difficult to work out the details of what those are, or even some sort of approximation that you could get a computer to use" (Piantadosi et al., 2012). The problem of ambiguity arises both when machines try to cope with human language, and when we use ambiguous key words in a search engine on Internet, and the system retrieves information that we have no interest in because it does not know which of two meanings we are referring to.
In machine translation, for a computer it is almost impossible to distinguish between the different meanings of word that may be translated in different ways in the target language. Over 40 years of research, all attempts to use computers alone to process natural language have been failed because of the computer's limited ability to deal with ambiguity (Portner, 1998). Efforts to solve the problem have focused on two potential solutions: statistical systems and knowledge-based systems. In the first approach, an enormous corpus of annotated data is required. The NLP developers then write procedures that compute the most likely resolutions of the ambiguities, given the words, classes of words and other easily determined conditions. In the second methodology, the NLP developers must encode a great deal of knowledge about the world and develop algorithms to use it in understanding the sense of the text.

The reality is that a computational system capable of determining the intended meanings of words in discourse does not exist today. Nevertheless, solving ambiguity problem – and other questions connected to the fuzzy and undetermined nature of meanings - is so important that all efforts will continued by linguists and computer scientists.

1.4 Ambiguity and creativity

In creative, aesthetic and artistic domains, language ambiguity is a surplus, which creates surprise, interpretative richness, imaginative blackouts, sense of loss in the lector. Sometimes, ambiguity is intentionally used to produce wordplays, riddles, irony and rhyme. In poetry, there is a pervasive use of figurative language – that is, full of figures, like metaphors, synecdoches, ermethic words, etc., which are characterized by shifts from the literal, ordinary meaning.

The productive ambiguity of good poems obliges the reader actually to *participate* with the text, as a co-maker of meaning. As poet and critic William Empson wrote in his influential book *Seven Types of Ambiguity* (1930), "The machinations of ambiguity are among the very roots of poetry." A poet may consciously join together incompatible words to disrupt the reader's expectation of meaning. The ambiguity may be even less deliberate, steered by the poet's attempts to express something ineffable, as in Gerard Manley Hopkins's "The Windhover". At the sight of a bird diving through the air, the speaker marvels, "Brute beauty and value and act, oh, air, pride, plume here / Buckle!" The ambiguity of this phrase lies in the exclamation of *buckle*: the verb could be descriptive of the action, or it could be the speaker's imperative. In both cases, the meaning of the word is not obvious from its context. Buckle could mean "fall" or "crumple," or it could describe the act of clasping armor and bracing for battle. Also advertisement creators play with language ambiguity, to produce appealing slogans and charming double senses. The goal is stimulate the attention of users, reinforce their cognitive efforts and, finally, invite to buy the product. For instance, in the headline of Sun

“Following last month’s figures we’d like to recommend an insertion: The Sun now outsells the Mirror”, the ambiguous word *insertion* – act of putting in vs. publication – is disambiguated by the visual, which represents a waste basket in which is put the competitor DailyMirror.

At theatre, as well as in sit-coms and movies, ambiguity is at the basis of many sketches, funny gags and misunderstandings which produce hilarity. In the human daily communication, finally, almost every word, even the most trivial, can assume new, creative and unexpected meanings attributed by speakers, but without damage the mutual comprehension.

1.5 CONCLUDING REMARKS

In this chapter I provided a definition of language ambiguity concept and a general overview of how it works in human communication.

Summing up:

- Language ambiguity is a pervasive phenomenon of natural language which characterizes almost all languages. Routinely speakers encounter linguistic material which can be interpreted in different way.
- As proof of how cognitive and linguistic skills are extremely sophisticated, disambiguation process is something that speakers handle effortlessly and unconsciously.
- Language ambiguity occurs at many levels of linguistic analysis: morphological, phonological, lexical, syntactic, pragmatic. In some cases, an ambiguity at one level can generate ambiguity at another level.
- Lexical ambiguity is the most common type of ambiguity: it can be distinguished in two types: homonymy (multiple unrelated meanings) and polysemy (multiple senses sharing a single core meaning).
- Language ambiguity is a relevant challenge for computational linguistics and natural language processing developers: over 40 years of research all attempts to use computers alone to process natural language have been failed because of the computer's limited ability to deal with ambiguity.
- In creative, aesthetic and artistic domains, language ambiguity is a surplus, which allows artists to play with language and use it productively.


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CHAPTER 2

ISSUES ON LEXICAL AMBIGUITY RESOLUTION PROCESSES

2.1 Introduction

In the previous chapter I focused on language ambiguity as a pervasive and almost universal phenomenon of human communication, which potentially occurs at all levels of linguistic analysis (syntactic, lexical, phonological, etc.). In particular, I discussed the paradox of how perfectly speakers tolerate semantic ambiguity, which sometimes enlarges the functional potentialities of the language, but also how its description and representation is yet a huge challenge for computational linguistics, lexicographers and NLP developers. From now on, I will focus on lexical ambiguity, which occurs at single word level.

One of the goals of theoretical Linguistics has been to analyse the semantics of lexical ambiguity and the dichotomy polysemy/homonymy, to demonstrate that lexical ambiguity is not a uniform phenomenon (Cruse, 1986; Lyons 1977). Psycholinguistic research has often dealt with lexical ambiguity, but has generally overlooked the semantics and its different typologies. Most work in psycholinguistics has concentrated on homonymy, to test models and theories of lexical access (Schreuder & Flores d'Arcais, 1989).

Finally, neurophysiological and neuropsychological studies on lexical ambiguity comprehension in both normal and brain-injured subjects aimed at localizing the neurological substrate for linguistic processing.

2.2 Linguistic accounts on lexical ambiguity phenomenon

Although homonymy has been studied in countless psychological experiments (see Simpson, 1994 for a review), polysemy has been much investigated in linguistics, both from a theoretical and a computational perspective.

Indeed, the phenomenon is far more frequent in natural language: most content words are polysemous to some extent, and the more frequent a word is, the more polysemous it tends to be (Zipf, 1935). One can verify this assertion by looking in a dictionary and noticing that several words have multiple entries. Caramazza and Grober (1976), for instance, identified 26 distinct senses for the word *line* and 40 senses for *run*. Thus, speakers and listeners must solve the problem of polysemous ambiguity in almost every sentence they utter and hear.

Many debates on polysemy concentrated on the description of the phenomenon, which can be further divided into two types (Apresjan, 1974). The first type of polysemy is motivated by metonymy. Metonymy[1], coming from ancient Greek μετονομασία (metōnumia, "change of name"), from μετά (meta, "other) + ὄνομα (onoma, "name"), is a figure of speech where a single characteristic or detail of an object is used to evoke or identify a related object, on the basis of a semantic relation principle.

In polysemy motivated by metonymy, the relation between the senses of the word lies on connectedness or contiguity. In metonymic polysemy, both the basic and the secondary senses are literal. For instance, the ambiguous word *chicken* has the literal basic sense referring to ''the animal'' and the literal secondary sense of ''the meat of that animal.''

[1] Metonymy is also the rhetorical strategy of describing something indirectly by referring to things around it, as in describing someone's clothing to characterize the individual. An example of metonymic word is the usage of the word *crown* to intend the *royalty*.

The second type of polysemy is allowed by metaphorically motivated. Metaphor[2] (from ancient Greek μεταφορά, metaphérō, «I carry») is a *tropo* (a figure of speech which subsumes a meaning transfer), which occurs when a term or phrase is applied to something which it does not literally apply to in order to suggest a resemblance, as in “A mighty fortress is our God.”

In metaphorical polysemy, a relation of analogy is assumed to hold between the senses of the word. The basic sense of metaphorical polysemy is literal, whereas its secondary sense is figurative. For example, the ambiguous word ‘‘star’’ has the literal basic sense ‘‘shining celestian body’’ and the figurative secondary sense ‘‘celebrity’’.

Consistent with the theory that homonymy and polysemy are fuzzy categories, it seems that some types of metaphorically motivated polysemy are closest to homonymy. Indeed, the phenomenon is quite unconstrained: in some cases the two senses share a sufficiently large core meaning, but in other cases the relatedness is not so transparent. On the other hand, metonymically motivated polysemy seems to be at the other end of the continuum, further away from homonymy (Apresjan, 1974). This kind of polysemy respects the usual notion of polysemy, which is the capability of a word to have distinct but related meanings.

Continuing the work of Apresjan (1974), Nunberg (1979), further observed that the changes of meaning in metonymic polysemy are not accidental, as in the case of homonymy, but systematic, or ‘‘regular,’’ as Apresjan (1974) called them. These changes of meaning can be explained by means of a function, which he called the *referring function* (RF). The RF, that has the general interpretation ‘‘x for y”, is a linguistic process which allows speakers to use the same expression for referring different conceptual categories. The idea is that when we cannot point at the referent itself, we can identify it by pointing at something, called the *demonstratum*, which stands in a certain unique relation to the *referent* (Nunberg, 1979). Some examples of RF: container/containee alternations (e.g., ‘‘bottle’’),

[2] Metaphor differs from similitude because comparison adverbs or locutions like “as” are not phonologically realized. It is not totally arbitrary: generally it is based on a resemblance relation between literal word and metaphorical form, but the communicative power is far stronger as the two terms are semantically far from each other.

producer/product alternations (e.g.,‘‘Monet’’), count/mass alternations (e.g., ‘‘lamb’’), and place/people alternations (e.g., ‘‘Milano’’). These shifts of meaning, which seem to hold cross-linguistically to a great extent, are systematic in nature and, thus, in a way, predictable and productive (Copestake & Briscoe, 1995).

Another theoretical approach to the study of lexical ambiguity consisted in focusing on how multiple meanings/senses are stored. According to some linguistic models called Sense Enumeration Lexicons (SEL), speakers understand words by means of a selection process of the meaning from a short enumerable list of potential senses stored in mental lexicon (Clark & Gerrig, 1983). As far as lexical ambiguities are concerned, SELs’ assumptions are the following:

1) all meanings of an ambiguous word are separately stored;

2) the right meaning is selected starting from this list.

Thus, this approach does not predict any distinction between homonymy and polysemy about how meanings and senses are lexically represented (Kempson, 1977; Weinreich, 1966).

SEL models, however, have several inadequacies. First of all, they cannot take into account that language is an extremely creative ability, and words can assume new nuances of sense depending on the context in which they occur. It seems too restrictive to consider mental lexicon as a mere set of exhaustive lists which contain meanings. Furthermore, a system like this appears to be excessively redundant, not cognitively economic. Sense Enumeration Lexicons assume a new representation for every use of a word, leading to an unrealistic, extremely overloaded lexicon.

Another theoretical approach has been more recently proposed within computational linguistics to overcome SELs’ limitations. Models within this approach are called “Generative Lexicons”, because they predict that the multiple senses of words are not listed, but rather generated from one central sense (Copestake & Briscoe, 1995; Pustejovsky, 1995). Thus, the mental lexicon is seen differently: it is not a static container of word senses where everything is stored, but rather an active ‘‘generator’’ of new meanings. More in detail, for each ambiguous word a semantic core set is assumed, from which new nuances of sense are created and specific aspects of meaning are highlighted, depending on context and communicative intentions of speakers. Moreover, generative lexicon accounts predict not only that senses are stored in lexicon, but also which lexical rules are used to operate on the basic sense to generate the extended senses. Finally, these models are able to take into account the homonymy/polysemy distinction. While distinct meanings of homonymous words are represented separately, in the case of polysemy only the central meaning is stored, and the extended senses are created from it, time by time.

The two theoretical perspectives about how meanings are stored in mental lexicon make different predictions about the processing of ambiguous words. In particular, the Sense Enumeration Lexicon account predicts that all ambiguous words are processed in a similar way, given that both homonymous and polysemous words have similar representations[3]. Conversely, the generative lexicon account predicts that the processing differences depend on the type of ambiguity.

2.3 Psycholinguistic approaches to lexical ambiguity resolution

A major issue in Psycholinguistics is how readers or listeners are capable of understanding language in the fast and efficient way they do. The question becomes evident if we realize that a language user has a passive knowledge of more than 50,000 words. Research has shown that on average three words per second are recognized — that is, are processed for meaning. A fundamental question is how we — apparently without any difficulty — succeed to select the right words from this huge database, and how we access their meanings. This ability is even more remarkable if we consider that language is full of ambiguities at several levels (e.g., phonological, syntactic, semantic). The focus in psycholinguistic literature has been on ambiguities at the semantic level and, specifically, on

[3] For a more detailed review of psycholinguistic studies on differences in lexical representations and processing between homonymy and polysemy, see Chapter 3 of this thesis.

homonymy. A famous example is the word *bank*. Here the same orthographic and phonological form can refer either to a financial institution (the money meaning), or to a stretch of land along a lake or river (the nature meaning). Disambiguation of the appropriate meaning of ambiguous words can only occur on the basis of contextual information. The word *bank* in the context of a robbery activates the money meaning, whereas the same string in the context of an excursion activates the nature meaning. The influence of context is so strong that we are usually not even aware of a possible conflict between different meanings.

Over the past 40 years, psycholinguistic research on lexical ambiguity resolution has provided a substantial body of evidence as well as theoretical accounts of how ambiguous words are processed, with a main focus on the investigation of context effects (for a review, see Simpson, 1994).

If it has not been a matter of debate that context information affects ambiguity resolution process, the question which inspired several experimental studies was to investigate how context operates, and at which stage of lexical processing. Thus, lexical ambiguity resolution over the years has become a test bench for theories on language processing (Duffy, Kambe & Rayner, 2001; Sereno, Pacht, & Rayner, 1992) and in particular for modular/interactive approaches to lexical access.

2.3.1 Modelling lexical ambiguity resolution

A long debate has dealt on whether the various language-processing subsystems (e.g. lexical and discourse subsystems) interact with each other or are autonomous. The literature offers two opposite positions.

Early psycholinguists, following Chomsky, tended to see language as an autonomous system, insulated from other cognitive systems. According to the modular view (Fodor, 1983; Forster, 1979), word and sentence comprehension is the result of many different modules, each devoted to a particular level of processing (orthographic, semantic, etc.). The initial stages of language comprehension are not influenced by higher levels of knowledge: information about context and real-world constraints comes into play only after the first steps of linguistic processing have taken place, giving such models a serial setting.

On an interactive view (Marslen-Wilson & Tyler, 1980; Marslen-Wilson & Welch, 1978; McClelland & Elman, 1986), in contrast, knowledge about linguistic context and the world plays an immediate role in the comprehension of words and sentences. In this view, many types of information are used in parallel, with the different sources of information working cooperatively or competitively to yield an interpretation. For example, constraint-based model (MacDonald et al., 1994) predicts that speakers simultaneously use all available information in their initial parsing - syntactic, lexical, discourse, as well as nonlinguistic, contextual information. Such ideas are often expressed in connectionist terms.

Researchers have been interested in ambiguity because studies on this phenomenon provide insights into whether processing at the lexical level is influenced by top-down information or it is an autonomous module. On the basis of these two alternative perspectives of lexical processing (interactive vs. modular) and in order to provide empirical evidence supporting one or the other of them, several models of ambiguity comprehension have been proposed.

According to the *exhaustive* or *multiple access model* (Ahrens, 1998; Conrad, 1974, Lucas, 1987; Onifer & Swinney, 1979; Swinney, 1979; Seidenberg, Tanenhaus, Leiman and Bienkowski, 1982; Tanenhaus, Leiman and Seidenberg, 1979), when speakers encounter an ambiguous word all the alternative meanings are activated (access stage). Only in a later post-lexical phase (interpretation stage) sentence context is used to select the appropriate meaning from the output of the lexical module. This model has generally gained most acceptance and is compatible with a modular account of language comprehension processes. Another peculiarity of this model is that the early stage of meaning access is not sensitive to so-called *dominance effects*, that means the alternative meanings are activated in parallel and not ordered by their relative frequencies.

Thus, most ambiguous words are used more frequently in one meaning (dominant) that in the other one (subordinate). For example, if we checked in a corpus representative of spoken English we would notice how a word like *panel* is much more used in the meaning of 'group of experts' rather than in the meaning of 'broad, metal sheet'. Obviously, the relative frequency of each meaning may also result from idiosyncratic linguistic uses and exposition contexts among speakers. For example, in the case of a word like *cram*, a university student would be more likely to activate the meaning of studying, rather than the meaning of try and squeeze something into an insufficient space, although the second one is actually more frequent.

In order to take into account dominance effects, Hogaboam and Perfetti (1975), and then Simpson and Burgess (1985) formulated the so-called *ordered access model*. Like the exhaustive access model, this approach maintains that the preceding context does not affect lexical access at an early stage; instead of a parallel and simultaneous access of all meanings they proposed that meanings are accessed in a sequential way, starting from the most frequent one. A similar account is offered by Rayner and Frazier (1989), who endorsed the *integration model*, which incorporates the dominance effects in the modular view of meaning access. According to the integration model, first the most frequent meaning is accessed and integrated with context information. If the integration is acceptable, the search process ends. Alternatively, if it does not fit the sentence context, the second meaning ordered for relative frequency is retrieved. This process goes on until an acceptable match is found.

A further perspective is provided by the so-called *selective* or *context-dependent access model* (Glucksberg, Kreuz & Rho, 1986; McClelland, 1987; Simpson, 1981; Simpson & Krueger, 1991; Swinney & Hakes, 1976; Vu, Kellas & Paul, 1998), which is most compatible with an interactive conception of language comprehension. According to this model, sentence context plays a prelexical role in the process of meaning access: it can be used to access the right meaning of an ambiguous word at an early stage of access (probably before the word is completely processed). Only the appropriate meaning of ambiguous word is activated, even if it is the subordinate one. Selective model predicts what happens even in absence of contextual disambiguating information: in this case, access to meanings is ruled by their frequency dominance. Experimental evidence obtained more recently reinforced the idea that lexical processing, although strongly autonomous, cannot be totally insensitive to extra-lexical information. (Dopkins, Morris & Rayner, 1992; Tabossi, 1988; Tabossi, Colombo & Job, 1987). Nowadays, researchers seem to prefer more restricted paradigms, able to provide a hybrid viewpoint for the issue. There is a general agreement about the fact that both contextual information and dominance effects play a role in lexical ambiguity resolution, even they do not strictly constrain the access to multiple meanings.

A proposal is the so-called *reordered access model*, (Duffy, Morris e Rayner, 1988; Rayner, Pacht e Duffy, 1994), which predicts that a strongly biasing sentence context preceding an ambiguous word cannot obstruct multiple access stage, but increases the availability of the appropriate meaning. Duffy et al. (1988) investigated context effects on balanced and unbalanced homonyms through eye-movement studies. The results showed longer latencies only for words with a subordinate meaning. Their interpretation is that, in the case of balanced homonyms, the meaning biased by context is activated before than the other one; in the case of unbalanced ambiguous forms, instead, both meanings are activated contemporarily, but subordinate meaning needs more time to be processed. This additional time is called *subordinate bias effect* (Rayner et al., 1994). According to the reordered access model, however, the role of context is restricted to dominance effects. Indeed, a context biasing towards the subordinate meaning cannot prevent the dominant meaning from being activated. An alternative perspective is the *context-sensitive model* (Simpson, 1994; Vu, Kellas e Paul, 1998), which predicts a cooperation of context and dominance effects. What is important for this model is the strength of contextual information, which means how much a sentence preceding an ambiguous word is able to bias towards one of two meanings, totally excluding the alternative interpretation. According to this model, the subordinate bias effect – which refers to the hypothesis that ambiguous forms need much time to be processed when context biases towards the subordinate meaning – is found only in the case of a weak context. On the contrary, if context information is sufficiently strong, only the subordinate meaning is accessed. In this case, the subordinate bias effect would be abolished. In Figure 2.1, a schematic description of the main ambiguity resolution models is reported.

SENTENCE CONTEXT EFFECTS

DOMINANCE EFFECT	POSTLEXICAL	PRELEXICAL
NOT BEING CONSIDERED	*Exhaustive* or *multiple access model* (Onifer & Swinney, 1981; Swinney, 1979; Tanenhaus et al., 1979)	*Selective access model (*Simpson, 1981), also called *strictly selective access account* (Ahrens, 1998)
BEING CONSIDERED	*Ordered access model* (Hogaboam and Perfetti, 1975 *Integration model* (Rayner and Frazier, 1989)	*Reordered access model* (Duffy et al., 1989; Sereno, 1995) *Context-sensitive model* (Simpson, 1994; Vu, Kellas e Paul, 1998)

Figure 2.1 Ambiguity resolution models

In the following paragraphs, a review of the most relevant studies on lexical ambiguity resolution carried out with several methodological paradigms and experimental tasks will be provided.

2.3.2 An overview of lexical ambiguity processing among research paradigms and empirical evidence

Researchers have used a variety of approaches to investigate lexical ambiguity in sentence processing. The classes of methods used most frequently in the earlier literature on this topic can be divided at least in three typologies: ambiguity detection, processing complexity tasks and priming paradigms. Most recent methodological lines include also neural and computational approaches.

Ambiguity detection. In this task, participants are asked to decide as fast as possibly if the homograph presented at the end of a sentence has another meaning (Forster & Bednall, 1976; Hogaboam & Perfetti, 1975; Neill et al., 1988).

Hogaboam and Perfetti used sentences biasing towards the dominant meaning ("the accountant filled his pen with ink", in the sense of 'object used to write') or towards the subordinate meaning ("the farmer put the sheep in the pen", in the sense of 'closed space') of homonymous words. The results show that participants were slower to detect ambiguity when target word was used with its more common meaning. This is because subjects activated automatically the most frequent meaning of 'pen', also helped by context, but they had to re-analyse the sentence in order to "discover" the other meaning of the word.

In sentences biasing towards the subordinate meaning of 'pen', people tried to interpret the word with its more common meaning, but the integration with context failed; thus, they accessed the subordinate, contextually appropriate meaning. Here, ambiguity detection occurs at an early stage, during the process of sentence comprehension. The results have been replicated by Neill et al. (1988) in an experiment where strategies of subjects were better controlled. The authors argued for a model which predicts a parallel access for all meanings, but that is sensitive to the context and frequency meanings.

Ambiguity detection studies were strongly criticized over the years because this method does not seem to capture on-line processes by identifying relative activation levels. Anyway, this methodological approach was crucial because for the first time it focused on meaning dominance, a factor largely ignored until the mid 1970s (Forster & Bednall, 1976).

Processing complexity tasks. In this class we include all tasks that infer the activation of one or more meanings based on a comparison of sentences containing homographs with unambiguous control sentences (Simpson, 1994). For example, sentence verification, phoneme monitoring (Ferreira & Anes, 1994), sentence completion, dichotic listening. Most experiments carried out over '60s using these methods tried to confirm the hypothesis of an exhaustive access of multiple meanings.

In sentence completion studies – where participants are asked to complete appropriately the syntactic fragments - MacKay (1966) found longer completion latencies for sentences containing ambiguous words[4]. Foss (1970) replicated these findings in phoneme monitoring tasks. Subjects were asked to supervise a specific sound or phoneme during the presentation of spoken material and to push a button when they listen to it. Foss found that when phoneme target was preceded by an ambiguous word, participants were slower to perform the task because they were busy to disambiguate preceding material[5].

One problem of these experiments is that performance can be affected by other linguistic variables, such as length of the preceding word. Indeed, Mehler, Segui e Carey (1978), failed to replicate these findings in phoneme monitoring studies where ambiguous words were balanced for number of letters.

Generally speaking, by using these methods it was found that the performance was worse in presence of ambiguous material because of extra-processing caused by the necessity of selecting the right meaning after that all meanings were previously activated. Most of these techniques have seen a decline of their use in recent years, because they showed several inadequacies.

First of all, these methods are criticized because they are "off-line" tasks, unable to track sensitively the time course of lexical access processes. Thus, it appears hard to understand if the results obtained in processing complexity tasks are traceable to initial meaning activation or to later selection processes that take place after multiple meanings have been already activated (Simpson, 1994).

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[4] In sentences used by MacKay (1966), context did not resolve ambiguity, because it was compatible with both meanings of homograph. For example: (1)"After taking the right turn at the intersection, I…" vs. (2) "After taking the left turn at the intersection, I…". The word "right" could be interpreted both as "direction" and "correct" . Participants needed more time to complete sentence (1) than sentence (2).

[5] In phoneme monitoring studies carried out by Foss (1970) sentences were strongly biasing towards one of multiple meanings of homograph. Anyway, longer latencies were found for sentences with ambiguous material, which could be interpreted as an evidence of the fact that at an earlier stage of processing all meanings are activated, nevertheless context indications.

Secondly, these research paradigms represent only indirect measures of meaning activation: the exhaustive access is just inferred from the increased processing time, but the specific activation levels of each meaning cannot be disentangled (Neill, Hilliard & Cooper, 1988).

At the end of '80s, one task that is based on a processing complexity measure has been frequently used to investigate ambiguity resolution processes: eye-movement techniques (for a review, see Duffy, Kambe, & Rayner, 2001). In these studies, participants are asked to read some sentences: the critical measurement includes both the first fixation duration (FFD) and the gaze duration (GD) to either the ambiguous word itself in the ordinary eye-tracking procedure (e.g. Carpenter & Daneman, 1981), or the target word in a priming paradigm (e.g. Sereno, 1995). FFD stands for the subject's initial fixation to a region or a word and GD stands for the total duration of all fixations before the eye fixation moves to another region or word[6]. What is measured is the fixation time on an ambiguous word, in comparison with the fixation time on an unambiguous control word. These techniques do not seem to be vulnerable to the criticism often raised against the other processing complexity off-line tasks. Indeed, eye-movement studies are an unintrusive on-line paradigm, because the fixation times are measured while subjects are simply asked to read texts. Furthermore, they allow to make more detailed inferences, concerning the nature of homographs, or the type of context. However, they still remain an indirect measure of meaning activation: for this reason, in more recent literature their use has been often associated with priming studies (see below) that better index activation levels but are more intrusive (Rayner & Morris, 1991).

Fixation time on an ambiguous word depends on certain aspects of the text as well as characteristics of the homograph itself. The first factor that affects fixation time is the location of context. The context can either

[6] There are still some disagreements about which stages of lexical processing FFD and GD reflect. Inhoff (1984) suggested that for low-frequency words FFD reflect only the lexical processing, but for high-frequency word they reflect also postlexical integration. However, it is possible that sometimes FFD underestimates and GD overestimates the time actually required by lexical access (Sereno, 1995).

precede the ambiguous word (biasing context) or follow it (neutral context).

The second variable is the type of homograph under investigation. Ambiguous words have been classified as either balanced or unbalanced, depending on the relative frequency of alternative meanings (Rayner & Duffy, 1986). Some ambiguous words are balanced, which means that their meanings are almost equal in terms of likelihood of occurrence, but most are unbalanced (or polarized), having one strongly dominant meaning and one or more subordinate meanings.

The third factor is the meaning of the ambiguous word that is instantiated by the context. Context can either select the more frequent, dominant meaning or the less frequent, subordinate meaning.

Following the initial Rayner and Duffy's study (1986), several eye-movement studies examining lexical ambiguity resolution have been reported (Binder, 2003; Binder & Morris, 1995; Binder & Rayner, 1998, 1999; Dopkins, Morris, & Rayner, 1992; Duffy, Morris, & Rayner, 1988; Folk & Morris, 2003; Kambe, Rayner, & Duffy, 2001; Rayner, Binder, & Duffy, 1999; Rayner & Frazier, 1989; Rayner, Pacht, & Duffy, 1994; Sereno, 1995; Sereno, Pacht, & Rayner, 1992; Wiley & Rayner, 2000).

The findings from such studies can be summarized as follows. When an ambiguous word appears in a neutral context, fixation times are longer on balanced ambiguous words than on unbalanced words or on unambiguous control words. However, when readers encounter the disambiguating information following the target, they spend more time on this region when it supports the subordinate meaning of an unbalanced homograph than in any other condition. When an ambiguous word appears in a biasing context, the pattern of results is quite similar: fixation times are longer when context supports the subordinate meaning than in the other conditions. These results have been referred to the so-called *subordinate-bias effect* (SBE; Pacht & Rayner, 1993; Rayner et al., 1994) and provided empirical support for perspectives like the *reordered access model* (Duffy et al., 1988) and the *integration model* (Rayner & Frazier, 1989), discussed in the previous paragraph. Recent debate has focused on the SBE, which, as mentioned above, predicts a pattern of results in which reading times are longer on ambiguous words than on unambiguous control words under the following specific conditions:

1) The ambiguous word is unbalanced;

2) a prior context instantiates the subordinate meaning of the word;

3) the control word is matched to the overall word-form frequency of the ambiguous word.

The data obtained are quite controversial. Using a probe-naming task, Kellas and colleagues have reported that the SBE can be eliminated under various contextual conditions (Kellas & Vu, 1999; Martin, Vu, Kellas, & Metcalf, 1999; Vu & Kellas, 1999; Vu, Kellas, Metcalf, & Herman, 2000; Vu, Kellas, Petersen, & Metcalf, 2003). Rayner and colleagues, however, using eye movements in reading, have been unable to replicate these findings (Binder & Rayner, 1998, 1999; Rayner et al., 1999). Similarly, a recent eye movement experiment by Kambe et al. (2001) reaffirmed the presence of the SBE. The reasons for these differences are somewhat unclear and could be related to differences in task, response-time measure, and stimulus materials.

Priming paradigms. Starting from the 1980s, studies on ambiguity resolution have been dominated by priming tasks. In these studies, participants hear or read a sentence containing an ambiguous word. Upon the presentation of this ambiguous word, a target word is presented for a speeded response, usually naming (NAM) or lexical decision (LD). It can be related to one of the multiple meanings of the ambiguous word or to an unrelated control word.

For decades, NAM and LD have been the most commonly used laboratory tasks for studying the cognitive processes involved in printed word identification (e.g., Jastrzembksi & Stanners, 1975; Rubenstein, Garfield, & Millikan, 1970; Zevin & Seidenberg, 2006). In LD task, the participant makes a speeded manual decision to a letter string shown on the computer screen: is it a word or not? In the NAM, the participant pronounces aloud, as quickly as possible, a word that is printed on the screen. In both tasks, the measures of interest are the speed and accuracy of response. A typical experiment includes hundreds of such events or trials. Because responses are speeded, the process of identifying a word is automatic, not particularly sensitive to postlexical strategies, and is thought to be similar to the word identification process in natural reading. LD and NAM have been employed frequently to assess models of printed word identification, lexical access, semantic and syntactic processing (cf., Feldman & Andjelkovic, 1992).

As far as priming paradigm is concerned, it has been well established that the processing of a target word (*nurse*) is faster and more accurate when it follows a prime word which is semantically related (*doctor*) than when it follows a semantically unrelated prime word (*bread*) (semantic priming, Meyer & Schvaneveldt, 1971). An usual interpretation of semantic priming (e.g., Collins & Loftus, 1975) is that a prime stimulus activates its corresponding internal representation (node) in memory, and such an activation spreads to other related nodes, thus facilitating the processing of related targets. The spread of activation in memory has often been considered as a fast-acting automatic process, occurring without intention or awareness (e.g., Posner & Snyder, 1975a; 1975b). Priming effects are also found for orthographically, phonologically and morphologically related primes.

a. Orthographically related: *dock* primes for *doctor*;

b. Phonologically related: *worse* primes for *nurse*;

c. Constituent morphemes: *legal* primes for *illegality*.

These all show us ways in which the mental lexicon is organized. Thus, there are many different ways to prime for a single entry in the lexicon – suggesting that the entries are linked to each other in several different ways.

Coming back to ambiguity resolution studies, priming technique has been implemented in several ways, varying according to the task performed on the target, the location of the ambiguous material, and the method of presentation of the sentence context.

A great deal of ambiguity research has used the cross-modal priming paradigm, with auditory presentation of an ambiguous word within a sentence context, followed by visual presentation of a probe word related to either the contextually appropriate or inappropriate meaning of the ambiguous prime (Conrad, 1974; Glucksberg et al., 1986; Lucas, 1987;

Oden & Spira, 1983; Onifer & Swinney, 1981; Seidenerg, Tanenhaus, Leiman & Bienkowski, 1982; Simpson, 1981; Swinney, 1979; Tabossi, 1988; Tabossi, Colombo & Job, 1987; Tanenhaus, Leiman, & Seidenberg, 1979).
For instance, Swinney (1979) used sentences like "*the man was not surprised when he found several bugs in the corner of his room*", where the ambiguous word is "*bugs*", which means both 'insect' and 'little microphone used as spy'. Half of participants were presented with the sentence associated to disambiguating material[7] (contained between brackets), biasing toward the most dominant meaning of 'insect'; the other half of subjects were presented with a neutral sentence, without any disambiguating context. Lexical decision on target stimulus could be made either immediately after having listened to the word 'bug', or delayed (three syllables after critical word). The target was either semantically related to the appropriate meaning of 'bug' (e.g. 'ant'), or semantically related to the contextually inappropriate meaning of 'bug' (e.g. 'spy').
Tanenhaus carried out cross modal priming naming tasks, in which critical stimuli were syntactically ambiguous words ("Boris began to watch", verbal meaning; "Boris looked at his watch", nominal meaning). Target words were presented either immediately after the ambiguous material, or delayed by 200 ms.
A much smaller number of studies used visual presentation of both the context and the target. In some studies, each sentence is presented word by word, using either a rapid serial visual presentation (RSVP) procedure in which each word replaces the previous one at the centre of the screen (Kintsch & Mross, 1985; Till, Mross & Kintsch, 1988), or an unfolding procedure in which each word appears to the right of the preceding word as it would in normal text (Paul, Kellas, Martin & Clark, 1992; Simpson & Krueger, 1991)[8]. In many studies involving priming paradigm the pattern of results is the following: when the probe is presented immediately after the offset of the ambiguous prime, a priming for both meanings of the

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[7] "The man was not surprised when he found several (spiders, roaches, and other) bugs in the corner of his room."
[8] There is no a reason to think that these differences in the way the context is presented should lead to different results (specifically, supporting context-dependent access rather than exhaustive activation). Indeed, the results cannot be divided in this way.

ambiguous word is found, regardless of context; alternatively, when the probe is delayed by 200 ms or more, priming to only the appropriate meaning occurs (Conrad, 1974; Lucas, 1987; Onifer & Swinney, 1981; Seidenberg et al., 1982; Swinney, 1979). Such results have generally been interpreted as supporting exhaustive access and the modularity of lexical processing, in which context only operates after a later, postlexical stage of processing after all meanings have been initially accessed (Fodor, 1983; Forster, 1979).

However, other studies have found priming effects only towards appropriate meaning even when the probe was presented immediately (Glucksberg et al., 1986; Oden & Spira, 1983; Simpson, 1981; Tabossi, 1988; Tabossi et al., 1987). Schvaneveldt et al. (1976) used the successive lexical decision task, where participants were asked to express lexical decision judgements on each word presented on the screen in speeded succession[9]. The triades were like the followings:

[2.1] save bank money
[2.2] river bank money
[2.3] day bank money

Schvaneveldt and colleagues reported faster latencies in the first condition, in which the financial meaning of ‘bank’ (consistent with the word ‘money’) was primed from ‘save’. In the second condition, latencies were much longer, depending on the fact that the inconsistent meaning of ‘bank’ was previously activated by ‘river’. In the control condition (third triad), reaction times were intermediate. If all meanings of the word ‘bank’ were automatically activated, the visual recognition of ‘money’ would be primed, regardless of which meaning was pre-activated.

These results are more consistent with selective access and interactivity, in which context directs the early, lexical selection of the appropriate meaning.

Likewise, some of the studies using visual priming support selective access (Paul et al., 1992; Simpson & Krueger, 1991), while the remainder find

[9] Compared with priming tasks, participants are less aware of semantic relations between words.

evidence for multiple access effects (Kintsch & Mross, 1985; Till et al., 1988). Furthermore, Lucas (1999) demonstrated that when results were combined across several cross-modal studies, the contextually appropriate meaning was more strongly activated (see also McClelland, 1987).

The brief review provided above does not paint a very encouraging picture, at least for the hope that ambiguity resolution studies may provide a definitive answer for issues concerning language comprehension processes (modular vs. interactive theories). On the contrary, data are so controversial that one could conclude that research on this topic has run its course. All the models of ambiguity processing have found empirical evidence from one or more researches. The constellation of results could be explained in virtue of the discrepancies among studies; anyway, there is no simple way of classifying results that sheds light on the real influence played by these methodological differences.

For example, it seems to be crucial the type of semantic priming employed in experiments. In many cross modal priming studies, participants listen to ambiguous words while they are reading target words: the partial overlap between the two lexical processes might cause a retroactive effect on word presented previously (*backward priming*). An unexpected effect of the context could result in the opposite direction, namely on the ambiguous word. (Glucksberg, Kreutz e Rho, 1986). Another relevant variable which could determine differences in experimental findings is the temporal interval between prime and target (SOA, Stimulus Onset Asynchrony).

It is well established that semantic priming effects can stem from both automatic processes and intentional mechanisms, depending on the temporal interval of presentation. If the speaker has not the time to respond (in the case of very short SOA), the activation spreading could be inferred to be automatic. Conversely, with longer SOA (e.g. 700 ms) intentional strategies are likely to occur. Thus, in order to understand meaning activation processes, experiments with short SOA should be preferable. On the contrary, studies with longer temporal intervals provide more detailed information on meaning selection/decision processes. Finally, the nature of sentence context could play a role in restricting more or less strongly the meaning activation of ambiguous words.

While discussions on context effects have been frequent in the ambiguity literature, there have been relative few attempts to develop a specific account of context types. Simpson (1981) used three kinds of sentences in a cross-modal priming experiment: unbiased, strongly biased towards a meaning, and weakly biased towards one meaning[10]. For example, for the homograph 'bank', the sentences were [2.4]-[2.8]:

[2.4] The men decided to wait by the bank. (unbiased)

[2.5] The fisherman decided to wait by the bank (weak bias-subordinate)

[2.6] The businessman decided to wait by the bank (weak bias-dominant)

[2.7] I pulled the fish up onto the bank (strong bias-subordinate)

[2.8] I opened a checking account at the bank. (strong bias-dominant)

The results show a quite clear empirical distinction between strong and weak context effects. In particular, the findings can be schematised like following: unbiased sentences facilitated the dominant meaning only; strongly biased sentences led to facilitation of the contextually appropriate meaning. Both frequency dominance and context played a role in weakly biased sentences: those biased towards the dominant meaning facilitated that meaning only, but in the case of weakly biased sentences towards the subordinate meaning both meanings were accessed.

More recent studies carried out on Italian ambiguous forms by Tabossi and colleagues (1988a, 1988b, 1991; Tabossi et al., 1987; Tabossi & Zardon, 1993) focused on the idea that context must activate certain kinds of activation in order to restrict access to a single meaning. Using cross-modal priming paradigm, Tabossi and colleagues showed how not all aspects of semantic-pragmatic context can restrict the meaning search process, but only those semantic features biased towards specific semantic proprieties can restrict the access only to the appropriate meaning.

For instance, a sentence like "*The little boy shuddered eating the lemon*" biases strongly towards the feature 'bitterness' of the lemon. Tabossi (1988a) found facilitation when a target word like

[10] Classification of the sentences was determined by subject ratings.

'*sour*' was presented immediately after the prime 'lemon' in the sentence context described above.

Surprisingly, the same target was not primed by sentences like:

[2.9] The little boy shuddered eating the popsicle

[2.10] The little boy rolled on the floor a lemon

In the sentence [2.9], although the context is the same, it does not bias towards the semantic feature 'bitterness', not typical of the popsicle. In the sentence [2.10], despite the presence of the word 'lemon', the context has changed: now it underlines the characteristic of the lemon 'to be a rolling object'.

The results were interpreted as an evidence that different types of context can restrict the meaning access more or less efficaciously. Simpson and Krueger (1991) replied these findings manipulating other types of semantic-pragmatic features of the context.

A criticism with respect to experiments carried out by Tabossi (1988a) is that SOA was too long to measure the meaning activation (Moss e Marslen-Wilson, 1993). Tabossi and Zardon (1993) replied findings of Simpson and Krueger in a cross-modal priming experiment in which target words were presented 100 ms before the ambiguous prime disappears. One more time, data suggest an exhaustive access to dominant and contextually appropriate meaning, in presence of a strongly biased context. Tabossi and Zardon found also that when context biased towards the less frequent meaning of the ambiguous word, both dominant and subordinate meanings were activated after 100 ms.

A series of studies by Kellas and his colleagues (Kellas, Paul, Martin & Simpson, 1991) investigated the topic on the importance of the feature activation for lexical access. Specifically, they called this factor 'salience', e.g. the overlap of semantic features between the homograph and the target word, given a certain context. On the basis of subject ratings, where participants were asked to produce all meanings come in mind one minute starting from an ambiguous word presented in a biasing sentence, target words could be identified as relatively high or low on a continuum of salience relative to the meaning of the homograph in that context. For example, subjects generated multiple associated words to a sentence such as *The boy dropped the plant,* instead of producing a single associate to a word such as *plant* in isolation (the same method used for association ratings). The most commonly response was *leaves*; anyway few subjects produced *spill* in response to the above sentence. In a Stroop experiment[11] (Paul et al., 1992) both *leaves* and *spill* (high and low-salient targets) showed slower colour-naming times than targets related to the other meaning (*factory*) even at an immediate context-target SOA. These results suggest that context can activate more information than simply the lexical associates of the homograph.

Alternative results were found by Till et al (1988), in which participants were asked to read sentences ending with an ambiguous word. The task consisted of a lexical decision on a target word presented immediately after the homograph. In this case, associates were obtained by means of a standard association procedure. For instance, given a sentence such as *The old man sat with is head down and did not hear a word of the sermon during mass,* speakers generated *sleep* as an inference target (*church* was the contextually appropriate associate target for the sentence, and weight was the inappropriate). Consistent with the multiple access hypothesis, both associates were primed following the sentence.

The discrepancy in these findings suggests that the approach to context must be undertaken very carefully. It does not seem clear to claim that a sentence context "biases one meaning" of an ambiguous word. The nature of the context and the types of semantic-pragmatic features implied in priming effects play a crucial role in constraining the degree of activation of meaning. It is crucial to expand the narrow definition of context, which has traditionally be intended only as the meaning conveyed within a single phrase. Factors like the sentence typology (e.g., single sentence vs. script-inducing), the type of task required, and even the procedure used to generate stimuli affect performances of subjects. Only by taking a broader

[11] In psychology, the Stroop effect is a demonstration of interference in the reaction time of a task. When the name of a colour (e.g., "blue," "green," or "red") is printed in a colour not denoted by the name (e.g., the word "red" printed in blue ink instead of red ink), naming the colour of the word takes longer and is more prone to errors than when the colour of the ink matches the name of the colour (Stroop, 1935).

view of context it will be possible to understand more clearly the nature of lexical ambiguity resolution and its relation to other aspects of language processing.

ERPs studies. Most electrophysiological studies have focus on lexical ambiguity resolution processes. Electroencephalography (EEG) is the recording of electrical activity along the scalp. EEG measures voltage fluctuations resulting from ionic current flows within the neurons of the brain (Niedermeyer & Lopes da Silva, 2004). Derivatives of the EEG technique include evoked potentials (EP), which involve averaging the EEG activity time-locked to the presentation of a stimulus of some sort (visual, sensory, or auditory); this technique is used in cognitive science, cognitive psychology, and psychophysiological research. Event-related potentials (ERPs) are sensitive to neural and psychological processes involved in human language (Brown, Hagoort and Kutas, 2000). For example, a component called N400, a negative potential who peaks at about 400 ms after the presentation of a stimulus (Kutas & Hillyard, 1980) has been demonstrated to be sensitive to the semantic congruency between a target and a prior context (Kutas & Hillyard, 1984). EEG and ERPs studies investigated the processing of dominant-related and subordinate-related targets in single word primes (e.g., Atchley & Kwasny, 2003), word triplets (e.g., Chwilla & Kolk, 2003; Titone & Salisbury, 2004), or sentence contexts (e.g., Swaab, Brown & Hagoort, 2003; Van Petten & Kutas, 1987).

ERPs studies are more sensitive to cognitive processes at an early stage of lexical access, allowing continuous measurements of the electrical cerebral activity. Using this experimental procedure, Van Petten and Kutas (1987) found that incongruent meanings were accessed slower than congruent ones, although there was no difference in reaction times. Furthermore, Swaab, Brown and Hagoort (1998) found that spoken sentence comprehension deficits in Broca’s aphasics did not stem from an inability to access the less frequent meaning of ambiguous words, but from delayed contextual selection of the appropriate meaning. This result was obtained measuring the amplitude of the N400 at two different interstimulus intervals (100ms and 1250ms).

Overall, findings obtained by these studies indicate that at short ISIs, both meanings are (partly) activated, regardless of the context (i.e., there are reduced effects for the N400 component which marks lexical-semantic processing). Conversely, at longer ISIs, only the contextually appropriate meaning is activated. The dominant meaning seems to be always partly activated (Swaab et al., 2003; Van Petten & Kutas, 1987).

Computational simulations. Computational models have also been used to investigate lexical ambiguity resolution processes. So far, most computational models of lexical ambiguity have focused on parallel processing, including Hopfield networks (Borowsky & Masson, 1996; Kawamoto, 1993; Kawamoto, Farrar & Kello, 1994) and models of prefrontal processing (Cohen & Servan-Schrieber, 1992; O'Reilly, 2002).

Kawamoto (1993) provided a connectionist model to take into account lexical resolution processes. The model assumes that all candidate meanings are activated, regardless of a possibly biased context information. According to this interactive view of the lexical access, the relatedness between perceptual form of a word (orthographic and/or phonological representation) and its meaning (more than one in the case of ambiguous words) would be stronger than the contingent relation between the meaning and the sentence context. The proposal by Kawamoto does not exclude context effects at an early stage of lexical access. Simply, it predicts that context – even if it is strongly biased towards only one of the possible interpretations – does not become so efficient to inhibit multiple access. Recently, a neural model of lexical ambiguity resolution based on known cortical regions activated during this process was proposed by Thivierge, Titone & Shultz (2005). Through the interaction of regions such as prefrontal and temporal lobes, the model is able to simulate findings associated with the time-course of meaning activation in context for ambiguous words whose multiple meanings are unbalanced in relative frequency. As in Kawamoto (1993), long-term memory (LTM) consists on distributed lexical knowledge, and context constraints are simulated by "pre-activating" the meaning units of the lexical representation of ambiguous words. The neural network processes the input by matching its activation to lexical representations stored in LTM. At the output, the network tries to reproduce the input as faithfully as possible. The model is able to capture the competition supposed among alternative semantic representations, as well as the final interpretation of the input word. Furthermore, the simulations succeed in showing both the impact of dominance effects and context pre-activation on the time-course of word activation.

Connectionist models have also addressed the idea that ambiguous words can be processed differently from unambiguous words[12]. In the psycholinguistic literature, it is often assumed that inhibitory processes play a relevant role in the meaning selection/decision mechanisms (e.g., Gernsbacher, Varner & Faust, 1990; Simpson & Kang, 1994). For instance, connectionist accounts (i.e., McClelland & Rumelhart, 1989) as well as connectionists models on lexical ambiguity resolution (i.e., Cottrell, 1989) predict the existence of passive inhibitory links among multiple meanings of ambiguous words.

2.4 Neurological basis of resolution ambiguity: evidence from neuropsychological and neurophysiological literature

A significant amount of research has been done in the field of lexical ambiguity comprehension in both normal and brain-injured subjects, in order to localize the neurological substrate for such linguistic processing. Right hemisphere function has often been assumed to be necessary for the successful comprehension of secondary meanings (Brownell, Potter, Michelow, & Gardner, 1984; Gardner, Brownell, Wapner, & Michelow, 1983). This includes alternative meanings of lexical ambiguous words (Chiarello, 1988) and the appreciate and integration of relationships in narrative texts and verbal discourse (Brownell et al., 1984), as well as the comprehension of jokes (Gardner, 1994).

Furthermore, in analysing the cognitive processes that are needed to interpret sentences containing ambiguous materials (in particular, the

[12] For a detailed review of studies on differences between ambiguous and unambiguous words in lexical representations and processing, see Chapter 3 of the thesis.

"abstract" demands in lexical access to multiple meanings), it seems that these can be localized in the frontal lobes. Thus, both left/right hemispheric asymmetry and anterior/posterior dichotomy of brain function are of equal importance when investigating lexical ambiguity.

Right hemisphere function and lexical ambiguity. Most studies with brain-damaged populations - both left-hemisphere damaged (LHD) aphasic patients and right-hemisphere damaged (RHD) patients - have been carried out to focus on neural substrates underlying the processing of ambiguous words. A great deal of studies have reported linguistic deficits of RHD patients in lexical ambiguity resolution process (e.g., Brownell, 1988; Brownell et al., 1984; Winner & Gardner, 1977). Generally, it has been found that the subordinate meaning of ambiguous words is less salient when the right hemisphere is damaged. Thus, two theories have been proposed to take into account these evidence: the "coarse semantic coding" and the "suppression" deficit.

According to the first theory, during lexical access the LH is most selective, strongly activating small subsets of semantic features, while the RH is more sensitive to sense nuances and can spread activation to large semantic fields. The hypothesis was formulated on the basis of the findings of a divided visual field study by Beeman et al. (1994) who, in a naming task with young healthy adults, visually presented unambiguous target words (e.g., "cut") preceded by either direct primes that show high feature overlap (i.e., three prime words, of which the first and third are "neutral," whereas the second is the direct prime that is very strongly related to the target; e.g., "none–scissors–whether"), summation primes that show less feature overlap (i.e., three prime words each weakly related to the target; e.g., "cry–foot–glass"), or unrelated primes (e.g., "dog–church–phone"). They found faster response times in the LH for targets preceded by direct primes than by summation primes or unrelated primes. In contrast, response times in the RH for targets preceded by either direct or summation primes were equivalent, and were faster than in the unrelated condition.

Over the years, a number of studies using the divided visual field paradigm, as well as with brain-damaged populations, have replicated this results, confirming the idea that the intact RH may sustain multiple interpretations of ambiguous words (Burgess & Lund, 1998; Burgess & Simpson, 1988; Collins, 2002) and distant semantic relations (Beeman et al., 1994; Chiarello, Burgess, Richards, & Pollock, 1990), whereas the LH selects close associations and a single interpretation for each word. For example, Burgess & Simpson (1988) carried out priming experiments on normal subjects in which ambiguous words were presented at the centre of the screen, followed by target words semantically related either to the dominant or the subordinate meaning. Target words were presented at different temporal intervals (35 and 750ms) and in both visual fields. Burgess & Simpson found that while the dominant meaning was activated in both hemispheres, the subordinate one was activated in the right hemisphere slower that in the left hemisphere, but its activation persisted longer.

A recent work by Collins (2002) tried to detail findings of Burgess & Simpson (1998) and other correlate studies (e.g., Collins & Coney, 1998), in order to investigate how inter-hemispheric cooperation occurs in processing alternative meanings of ambiguous words. Collins (2002) found that an ambiguous word activates a much wider set of meanings in the contralateral hemisphere than in the hemisphere which the stimulus was addressed to. These findings indicate a LH preference for closely related lexical items, since there was facilitation only when the prime was very strongly related to the target. On the other hand, the RH seems to have the ability to maintain wider range of concepts, since facilitation effects were observed after both strongly and weakly related primes.

As it has been reported above, the "coarse semantic coding" predictions mainly stem from evidence reported in divided visual field studies on normal individuals. Specifically, critical materials were presented either in the left visual field or in the right one, and reaction times were measured. The prediction is that subjects process faster stimuli which are presented in the contralateral side to the activated hemisphere.

Conversely, the "suppression deficit" hypothesis is based principally on the observation of brain-damaged populations' performances (Tompkins, Baumgaertner, Lehman, & Fassbinder, 2000; Tompkins, Baumgaertner, Lehman, & Fossett, 1997; Tompkins & Lehman, 1998). According to the "suppression deficit" theory, difficulties of RHD patients in processing ambiguous words may be due to problems with suppressing multiple interpretations that are initially activated, but are not consistent with the context. The idea is that the suppression mechanism would be less effective in speakers with RHD than in normal individuals, and suppression function after RHD is hypothesized to correlate with comprehension (Tompkins & Lehman, 1998).

Frontal lobe function and lexical ambiguity. Traditionally, damage to the frontal lobes has been associated with impairments in abstract thinking (Goldstein, 1948; Luria, 1966). More recently, it has been proposed that difficulty with lexical ambiguity involves problems with mental shift, considered as a cognitive function associated with the frontal lobes. Thus, brain damaged patients who are unable to shift from one interpretation of a concept to another one, would exhibit similar difficulties in handling lexical ambiguity.

Milberg et al. (1987) investigated the processing of lexical ambiguities in Wernicke's[13] and Broca's[14] aphasic patients in a lexical decision task. They were asked to make lexical decisions on the third word of an auditory triplet series of words. The first and third words of each triplet were related to one, both, or no meaning of the second word which was semantically ambiguous. Performances of Wernicke's aphasics were similar

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[13] Wernicke's aphasia is a type of aphasia often caused by neurological damage to Wernicke's area in the brain (Brodman Area 22, in the posterior part of the superior temporal gyrus of the dominant hemisphere). Speech is preserved but language content is incorrect. This may vary from the insertion of a few incorrect or nonexistent words to a profuse outpouring of jargon. Rate, intonation and stress are normal. Substitutions of one word for another (e.g. "telephone" for "television") are common. Comprehension and repetition are poor.

[14] Broca's aphasia is an aphasia caused by damage to anterior regions of the brain, including (but not limited to) the left inferior frontal region known as Broca's area. Sufferers of this form of aphasia exhibit the common problem of agrammatism. For them, speech is difficult to initiate, non-fluent, labored, and halting. Intonation and stress patterns are deficient. Language is reduced to disjointed words and sentence construction is poor, omitting function words and inflections (bound morphemes).

to normal speakers; they showed selective access to different meanings of the ambiguous words, as demonstrated by the fact that the *contest* provided by the first word affected semantic facilitation on the third word. In contrast, Broca's aphasics showed no semantic facilitation in the priming condition. These results are consistent with the idea that semantic representations may be largely spared in Wernicke's aphasics. Performances of Broca's aphasics seem to suggest that they have a deficit in accessing semantic information via automatic processing routines. This evidence is consistent with the idea that impaired processing of lexical ambiguity requires intact frontal function.

Evidence in favour of this neurological localization hypothesis of lexical ambiguity comes also from electrophysiological studies. In neuroimaging literature, the language system may be conceived as a number of modules, tightly interconnected and clustered and relatively small. Each of them is postulated to give a specific contribution to language processing (Bookheimer, 2002).

A recent fMRI[15] investigation has found evidence relating the involvement of prefrontal and temporal areas in the lexical disambiguation (Rodd, Davis & Johnsrude, 2005). Specifically, the modules involved in resolving lexical ambiguity would be three:

1) the left anterior and posterior ventro-lateral areas of the prefrontal cortex (VLPC);
2) the left inferior frontal gyrus (LIFG);
3) the left occipito-temporal and left parieto-temporal areas of the temporal cortex (TL).

This suggest a three-partite model involving frontotemporal pathways that connect the VLPC, LIFG and TL regions, as reported in the figure below.

[15] Functional magnetic resonance imaging (fMRI) is a procedure that measures brain activity by detecting associated changes in blood flow. This technique relies on the fact that cerebral blood flow and neuronal activation are coupled. When an area of the brain is in use, blood flow to that region also increases (Huettel, Song & McCarthy, 2009).

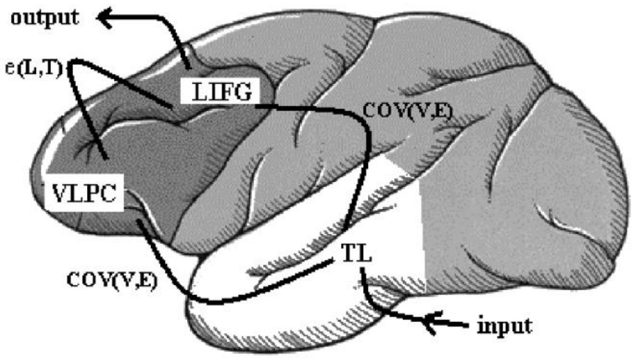

Figure 1.2 Brain regions

Despite the fact that also other regions are involved in lexical disambiguation, they presumably play a crucial role. The activity of the three regions is not modality-sensitive, that is they are activated both in the case of visual and auditory input.

EEG[16] studies have also provided substantial evidence for the centrality of these cerebral regions. For example, Baastianse, van Berkum & Hagoort (2002) have reported a rhythmic association in the theta band between the prefrontal cortex and the temporal lobe. Other authors have shown a stream of activation gioing from the temporal lobe to the prefrontal cortex in ERPs (Low et al., 2003), with early negativity (N400) in the occipo-

[16] Electroencephalography (EEG) is the recording of electrical activity along the scalp. EEG measures voltage fluctuations resulting from ionic current flows within the neurons of the brain (Niedermeyer & da Silva, 2004). Derivatives of the EEG technique include evoked potentials (EP), which involves averaging the EEG activity time-locked to the presentation of a stimulus of some sort (visual, sensory, or auditory); this technique is used in cognitive science, cognitive psychology, and psycho-physiological research. Event-related potentials (ERPs) are sensitive to neural and psychological processes involved in human language (Brown, Hagoort and Kutas, 2000). For example, a component called N400, a negative potential who peaks at about 400 ms after the presentation of a stimulus (Kutas & Hillyard, 1980) has been demonstrated to be sensitive to the semantic congruency between a target and a prior context (Kutas & Hillyard, 1984).

temporal lobe, and late positivity (P600) in the frontal lobe. MEG[17] studies also confirm a posterior to anterior response sequence in processing lexically ambiguous words.

These results suggest that the TL is the first region to receive language input. This module seems to be devoted to encode information and guide the activation of the other regions (Stowe et al., 2002). VLPC module works as a working memory (WM) for semantic information: it retrieves pertinent information from long-term memory (LTM) and re-formulates it in a useful form for the task at hand (Thompson-Schill, D'Esposito & Kan, 1999). Once some representations are retrieved in LTM and activated in VLPC, they compete by means of bilateral inhibitory links (Miller & Cohen, 2001). Finally, information is sent to LIFG region, which is involved in the selection of the appropriate meaning, after having "suppressing" the undesirable entries (Bookheimer, 2002).

[17] Magnetoencephalography (MEG) is a technique for mapping brain activity by recording magnetic fields produced by electrical currents occurring naturally in the brain, using very sensitive magnetometers. Applications of MEG include basic research into perceptual and cognitive brain processes, localizing regions affected by pathology before surgical removal, determining the function of various parts of the brain, and neurofeedback. Since the MEG signal is a direct measure of neuronal activity, its temporal resolution is extremely high (better than 1 ms), comparable with that of intracranial electrodes. MEG complements other brain activity measurement techniques such as electroencephalography (EEG), positron emission tomography (PET), and fMRI. Its strengths consist in independence of head geometry compared to EEG (unless ferromagnetic implants are present) and non-invasiveness, as opposed to PET (Cohen & Cuffin, 1983).

2.5 CONCLUDING REMARKS

In this chapter, I provided a substantial overview of the most relevant studies carried out over the last 40 years on lexical ambiguity resolution processes.

Summing up:

- In linguistic literature, most studies on polysemy focused on the description of the phenomenon, which can be further divided into two types: polysemy motivated by metonymy (e.g., *chicken*), and polysemy motivated by metaphor (e.g., *star*).
- Some linguistic accounts called "Sense Enumeration Lexicons" (SELs) and "Generative Lexicons" have differently modelled how multiple meanings/senses of ambiguous words are stored in the mental lexicon.
- Psycholinguistic researchers have been interested in ambiguity because studies of this issue may provide insight into whether lexical access is influenced by information at higher levels (e.g., context information) or whether it is autonomous (interactive vs. modular view of language processing).
- Behavioural, electrophysiological and computational evidence do not reveal such clear-cut interpretations: several models of how speakers disambiguate lexical ambiguities have been proposed.
- Nowadays, there is a general agreement about the fact that both contextual information and dominance effects play a role in lexical ambiguity resolution, even they do not strictly constrain multiple meanings access (hybrid viewpoint).
- A significant amount of research has been done in the field of lexical ambiguity comprehension in both normal and brain-injured subjects, in order to localize the neurological substrate for such linguistic processing.
- Neuropsychological and neurophysiological evidence supported the idea that both right hemisphere and frontal lobe functions would

be necessary for the successful comprehension of ambiguous words.


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CHAPTER 3

AMBIGUITY EFFECTS IN WORD PROCESSING: EVIDENCE AND UNSOLVED QUESTIONS

3.1 Introduction

Most psycholinguistic studies prior to '90s have been focusing on the role played by context in disambiguating words with multiple meanings, namely, in assigning them an interpretation consistent with sentence context. Specifically, these studies have addressed two issues:

1) understanding whether all meanings of an ambiguous word are initially activated regardless of context information;
2) investigating if access to meanings occurs according to the relative frequency of each meaning.

As reported in the previous chapter, in most priming experiments ambiguous words were presented in sentences, which either biased or unbiased towards a single meaning. Latencies to words related to one of the two meanings were measured.

In this chapter, I will report a brief review of the most relevant studies which investigated the lexical processing of ambiguous words presented out of context, in single word presentation tasks. The general aim of these works was to understand the impact of ambiguity on word processing. Specifically, they were directed to two issues:

1) how ambiguous forms are stored in mental lexicon and how their semantic representations are lexically accessed;
2) whether ambiguous and unambiguous words differ in the basic principles underlying their lexical representation and processing.

Such studies have also addressed a more general question in psycholinguistic research: whether semantic factors influence word recognition and at which stage of lexical access (see Rastle, 2007 for a discussion of the word recognition literature). In particular, the issue of efficiency in accessing a word depending on its number of meanings seems critical, as it sheds light on the representation of meanings in the mental lexicon as well as the amount of semantic information that is required to access a word.

After having reported the most significant findings on the topic in behavioural studies, I will discuss the attempts to model computationally how ambiguous words might be represented in memory. Next, more recent attempts to distinguish between different types of ambiguous words will be presented.

3.2 The ambiguity advantage effect in word recognition: a review of the first evidence

Upon presentation of an ambiguous word in isolation, we are normally able to identify an appropriate meaning and we are often unaware of alternative meanings. Most research that has compared the processing of ambiguous and unambiguous words in isolation proposed that ambiguous words have separate entries for each of their meanings (e.g., Forster & Bednall, 1976; Jastrzembski, 1981; Millis & Button, 1989; Piercey & Joordens, 2000; Rubenstein, Garfield, & Millikan, 1970). These studies reported faster reaction times for ambiguous words than for unambiguous words in visual lexical decision tasks; the phenomenon is known as the ‘‘ambiguity advantage’’ effect. This result, which seems counter-intuitive, as one might expect ambiguous words that have competing meanings to take longer to process, was explained within the framework of classical lexical models (e.g. Becker, 1980; Forster, 1976; McClelland & Rumelhart, 1981; Morton, 1969; Paap, Newsome, McDonald, & Schvaneveldt, 1982). In these accounts, orthographic representations are constructed on the basis of the perceptual input, and a lexical unit is then selected. At this point, sufficient lexical information would be available to license a positive response. Semantic information would become available only after having selected the appropriate lexical unit. Thus, according to the simple versions of these models, semantic information should not affect the lexical selection process. Rubenstein et al. (1970) and Jastrzembski (1981) provided a quite different viewpoint, assuming that ambiguous words are represented by multiple lexical units (basically one for each distinct, known meaning) whereas unambiguous words are represented by a single lexical unit.

Rubenstein, Garfield and Millikan (1970) were the first to compare the processing of homographs vs. non-homographs. The “status” of lexical ambiguity of each word was derived from a subjective rating procedure carried out by 20 participants. The results showed faster lexical decisions to ambiguous words than to unambiguous words matched for frequency and concreteness. Afterwards, Rubenstein, Lewis and Rubenstein (1971) reported that the ambiguity advantage was restricted to those ambiguous words that had two, unrelated, equiprobable meanings. The interpretation provided by Rubenstein and colleagues was that the identification of a word requires a random search within the mental lexicon, which involves only those words that have some orthographic resemblance to the visual input. Because ambiguous words have many lexical entries, the probability of rapidly selecting an appropriate unit for an ambiguous word increases, as compared to an unambiguous word, and produces a processing-time advantage for ambiguous words. Furthermore, it was hypothesized that these multiple entries do not actually inhibit each other in the process of word recognition but rather work together to inhibit any other competing lexical item.

Jastrzembski’s (1981) account of ambiguity advantage effect was based on the Logogen Model (Morton 1969). Like Rubenstein and colleagues, Jastrzembski also assumed that ambiguous words are represented by multiple lexical units (i.e., logogens), with different *logogens* corresponding to different meanings. According to this model, a word is recognized whenever the activation threshold of a logogen is exceeded. Since ambiguous words would activate more logogens than unambiguous words, the likelihood that any of these logogens reaches the threshold within a given time would be greater than for a single logogen within the same time. Thus, words with multiple meanings should be responded to more rapidly than unambiguous words.

These findings did not go uncontested. A great deal of attempts to replicate the ambiguity advantage effect gave discordant outcomes. Clark (1973) argued that it is important to treat items as a random factor in analyses of variance, in order to be able to generalize results from experiments contrasting two sets of stimuli (e.g., ambiguous words and unambiguous words) Specifically, he recommended a quasi-F (F') procedure in which the error terms in ANOVAs involved both subject and item variability. When Clark reanalyzed data of Rubenstein and colleagues using this technique, he failed to observe a significant ambiguity effect. Thus, the author concluded that the effect observed by Rubenstein et al. (1970) was due simply to the idiosyncratic nature of their materials.

However, as a number of researchers (Cohen, 1976; Keppel, 1976; Raaijmakers, Schrijnemakers & Gremmen, 1999; Smith, 1976; Wike & Church, 1976) have pointed out, generalizability is not a statistical issue. The only way to understand if an effect generalizes over items is by means of replication using new sets of items. Anyway, using item variability in analyzing data from language experiments is now a common practice. More importantly, Clark's analysis pushed researchers to focus on the existence of an ambiguity advantage. Afterwards, there was an increasing number of studies directed to investigate ambiguity effects in lexical processing.

Forster and Bednall (1976) found small and not significant ambiguity effects with both balanced and unbalanced ambiguous words. Categorization of words was done by subject ratings, as in Rubenstein et al. (1970). On the contrary, Jastrzembski and Stanners (1975) and

Jastrzembski (1981) reported an ambiguity advantage in a series of word recognition experiments, even using Clark's F' procedure. The status of ambiguity was established using meaning counts from dictionaries.

Their methodology was firmly criticized by Gernsbacher (1984), who argued that using meaning counts from dictionaries is incorrect to determine the number of meanings of a word. Firstly, it seems that there is not a real correspondence between dictionary definitions and the active semantic knowledge of the current speech community. Frequently, some meanings are so restricted to a specific terminological lexicon that only few people know them. In a survey, Gernsbacher (1984) found that even well-educated subjects such as college professors could report only a small proportion of the meanings listed in a dictionary[18].

Another problem of relying on dictionary meanings is that dictionaries do not necessarily adopt consistent linguistic criteria in providing definitions. Different sets of definitions are provided, and different ways to organize these meanings are adopted in different dictionaries. While some words have similar numbers of meanings in many dictionaries (e.g., *rare, trap, file*), others differ in the numbers of meanings (e.g., *cast, round*; Azuma and Van Orden, 1997; Lin and Ahrens, 2005).

Gernsbacher also noted that in none of the previous studies where an ambiguity advantage was reported the materials were balanced for "experiential familiarity"[19], a variable that she had demonstrated to be a better predictor of RTs than lexical frequency in lexical decision tasks. Using stimuli controlled for their rated experiential familiarity, Gernsbacher failed to replicate the ambiguity advantage.

Gernsbacher's argument was crucial for further investigations on ambiguity effects and, more in general, on lexical processing. Moreover, since then, much more attention was directed to how to collect the meanings of

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[18] For instance, for the word *gauge*, which has thirty dictionary meanings, several college professors provided only two meanings.

[19] Experiential familiarity is a subjective value referred to how many times a speaker has encountered a word in his life. It may be determined by means of subjective ratings, and it allows to predict quite reliably the knowledge degree of a given word (and its meanings) (see Gernsbacher, 1984, for a detailed discussion of the experiential familiarity concept.)

ambiguous words starting from the experience of language users. In their experiments, Millis and Button (1989) employed three different subjective ratings, in order to take into account the actual people's knowledge about word meanings. The first rating evoked Rubenstein et al.'s (1970) procedure: speakers were asked to record the first meaning that came to mind when reading a word. In the second, subjects had to record all the meanings come to mind when reading a word and the total number of meanings across all subjects was counted. In the third rating procedure, the average number of meanings generated per subject was counted. Experimental materials were selected using each of these measures (equating words sets on experiential familiarity). Lexical decision results showed an ambiguity advantage when ambiguity was defined using either the second or third measure and a large (87 ms) but not significant advantage using the first measure (using F' statistics). The authors argued that Rubenstein et al.'s procedure did not produce an ambiguity advantage because it did not adequately measure individual semantic knowledge. They suggested that the total and average numbers of meanings participants provided for each word better estimate the amount of semantic knowledge that language users are able to actively access on-line. Although Millis and Button (1989) did not replicate the null effect found by Gernsbacher, their data were consistent with the hypothesis that word features should be measured by determining how these properties are actually represented in minds.

3.3 Establishing the AAE in lexical decision and naming tasks: more recent studies

Many researchers replicated the findings of Millis and Button using the same rating procedure and reinforced the suggestion of an ambiguity advantage effect in word recognition tasks. Indeed, an increasing number of researchers reported that words with multiple meanings were responded to faster than words with fewer meanings in both lexical decision and naming tasks (e.g., Gottlob, Goldinger, Stone, & Van Orden, 1999; Hino & Lupker, 1996; Hino, Lupker and Besner, 1998; Hino, Lupker, Sears, & Ogawa, 1998; Kellas, Ferraro, & Simpson, 1988; Lichacz, Herdman, LeFevre, & Baird, 1999; Rodd, 2004).

Kellas, Ferraro and Simpson (1988) balanced stimuli for familiarity and also developed a procedure to determine the status of ambiguity: subjects were asked to rate words as to whether they had no meaning (0), one meaning (1) or more than one meaning (2). Using this method, the authors reported faster reaction times on ambiguous words in two lexical decision experiments. Hino and Lupker (1996), employed Kellas et al.'s procedure and reported different patterns of ambiguity effects in their lexical decision and naming tasks. Specifically, identical ambiguity effects were observed for both high- and low-frequency words in the lexical decision task (as in Rubenstein et al., 1970). In their naming task, however, the ambiguity effect was limited to low-frequency words. A similar interaction between ambiguity and frequency in naming was also reported by Lichacz et al. (1999). Hino and Lupker (1996) noticed that it is possible to reconcile these contrasting results through a lexical selection account. It could be assumed (Jastrzembski, 1981) that the lexical selection process is sensitive to both frequency and ambiguity. Thus, a frequency by ambiguity interaction is expected to arise during the lexical selection process. For example, it could be argued that since lexical selection for high-frequency words is much faster than the one for low-frequency words, the impact of ambiguity would be much greater for low-frequency words. Thus, the interaction that Hino and Lupker (1996) observed between frequency and ambiguity in a naming task would be explained. In a lexical decision task, however, the situation is somewhat different. As suggested by a number of authors (e.g., Balota, 1990; Balota & Chumbley, 1984; Besner, 1983; Besner & McCann, 1987; McCann, Besner, & Davelaar, 1988; Seidenberg, Waters, Barnes, & Tanenhaus, 1984), a lexical decision task involves a decision-making process following lexical selection, a process based on stimulus familiarity. Gernsbacher (1984) has argued that stimulus familiarity is correlated with both ambiguity and frequency. Thus, this decision making process would presumably be sensitive to both factors. As a result, the observed result pattern in lexical decision experiments would reflect not only the impact of lexical selection but also the impact of the decision-making process. In particular, it is possible that the relationship between frequency and ambiguity could shift from an interactive to an additive function if a larger ambiguity effect was produced for high-frequency words than for low-frequency words during the decision-making process.

Borowsky and Masson (1996) also observed an ambiguity advantage in lexical decision task using the procedure by Kellas et al., although they did not observe an advantage in their naming task. Rodd (2004) provided a reasonable explanation for the difference between the null effect reported in naming by Borowsky and Masson (1996) and the results reported elsewhere. Rodd showed that the effect size grows as a function of the difficulty of the words being named (i.e., the effect existed for irregular words but not for easy-to-name regular words). Borowsky and Masson used short and often regular words and obtained mean naming latencies between 494 and 508 ms, suggesting that any ambiguity advantage would have been small for those stimuli.

3.4 Modelling the AAE

3.4.1 The "localist" perspective: models based on multiple lexical units

As reported above, Rubenstein et al. (1970; 1971) proposed an account for the ambiguity advantage effect based on Forster's (1976) autonomous search model[20].

[20] According to this model, recovery of information from lexical memory during reading requires an extensive search process. Information about words is assumed to be stored in a set of files, or lexical entries, and when information about a given word is required, a search through a subset of these lexical entries is initiated, with the search being terminated when the correct entry is located. The evidence for a search process derives from two findings. First, in lexical decision tasks, orthographically legal nonwords (e.g., *thamon*) take longer to classify than words (Forster & Chambers, 1973; Rubenstein et al., 1970; Snodgrass & Jarvella, 1972; Stanners & Forbach, 1973). Second, high frequency words are classified faster than low frequency words (Forster & Chambers, 1973; Rubenstein et al., 1971).

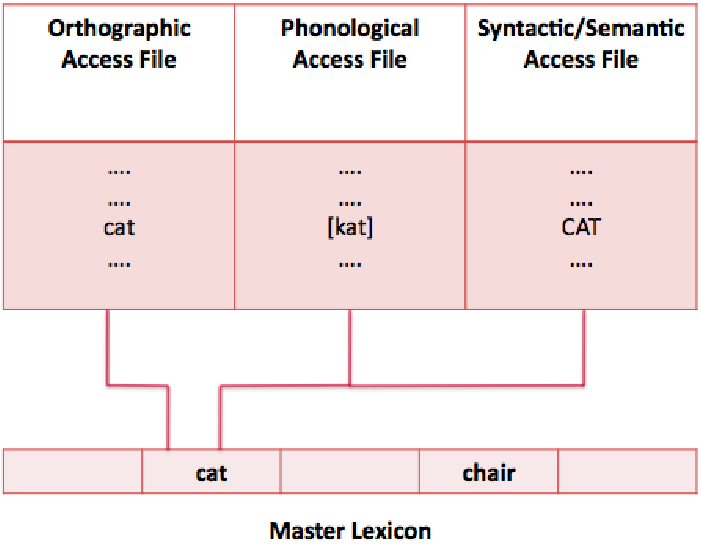

Figure 3.1 Search Model (Forster, 1976)

Within the model, each meaning of an ambiguous word has a separate lexical entry. Thus, on average, the random search through the marked entries would locate one of the multiple lexical entries for an ambiguous word more rapidly than the single lexical entry for an unambiguous word. However, the model cannot explain clearly the evidence provided by Rubenstein et al. (1970). For instance, if each meaning of an ambiguous word has a separate lexical entry, the frequency value of this lexical entry would, presumably, refer to the frequency of activation of that particular meaning (relative frequency value). Thus, this value is assumed to be lower than the frequency value of a matched unambiguous word. If so, the result would be an ambiguity disadvantage rather than an ambiguity advantage.

The first finding is explained by the fact that nonwords require an exhaustive search of the subset of the lexicon in order to determine that no entry is present, which must take longer than a self-terminating search for a word. The second finding is explained on the assumption that the most efficient organization of the lexicon would place the most frequently accessed words near the beginning of the list of entries to be searched.

The second attempt to explain the AAE was offered by Jastrzembski (1981). Differently from Rubenstein et al., he reported an interaction between frequency and ambiguity and proposed an activation account based on the logogen model[21] (Morton, 1969).

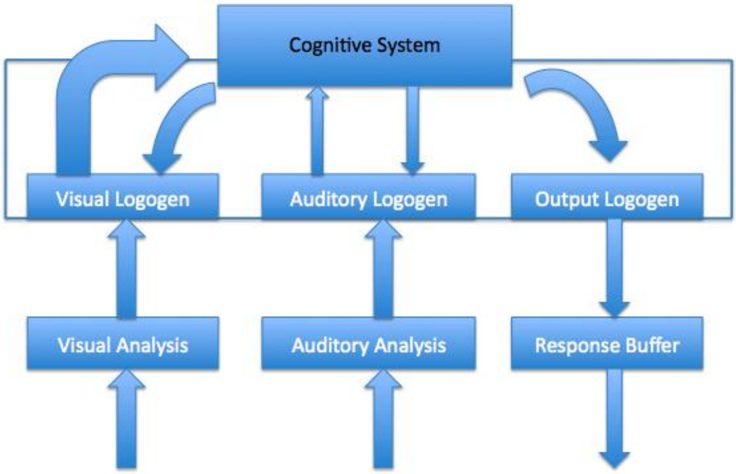

Figure3.2 Logogen Model (Morton, 1969)

The rationale was that ambiguous words have multiple logogens; the chance for any of them to reach the threshold quickly would be higher than the chance for single logogens of unambiguous words. The model did not take into account the problem of relative frequency value (as in Rubenstein et al., 1971).

Forster and Bednall (1976) provided an additional problem for these types of accounts. The authors carried out *an ambiguity decision* task where subjects were required to decide whether a given orthographic string was associated with more than one meaning or not. According to the search model, the method of reaching a decision would be to initiate a search,

[21] According to this model, each known word is represented by a logogen in the lexicon of a reader. In reading, word identification occurs when the activation of its logogen reaches a threshold value. The activation threshold for each logogen is a function of the word frequency: higher frequency words have lower thresholds and, hence, reach threshold more rapidly.

through the lexical entries with the required orthographic properties that are encountered. When the count reaches the number two, the search is interrupted, and the "Yes" response executed. As the count remains less than two, the search must be continued. Thus, for both unambiguous words and nonwords, an exhaustive search would be required.

The results partially confirmed this hypothesis: “yes” responses to ambiguous words were faster than “no” responses to unambiguous words and nonwords. No expected differences between balanced and unbalanced homographs were found. Presumably, in order to respond “yes”, readers must find both meanings (in a search context) or have both meanings activated over threshold (in an activation context). Thus, the frequency of the less probable meaning should determine response latencies. Therefore, words with unbalanced meanings should suffer in contrast to words with balanced meanings. For high and low frequency words there was no significant difference between the two ambiguous words types.

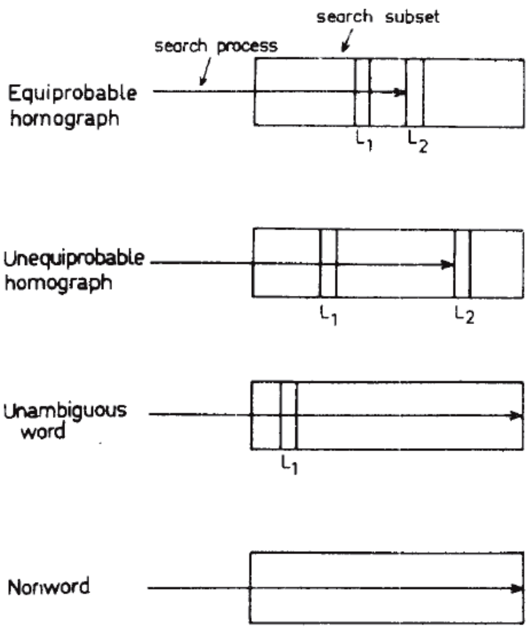

Figure 1.3 Forster & Bednall's Model (1976)

Up to this point, “localist” models[22] had become less popular and there was an explosion of models based on distributed representations.

3.4.2 The connectionist approach: PDP accounts of ambiguity effects

Connectionist models of word recognition assume that the process of retrieving lexical meaning does not involve a selection process, but rather is based on patterns of activation over sets of units representing orthographic, phonological, and semantic properties (e.g., Gaskell & Marslen-Wilson, 1997; Hinton & Shallice, 1991; Joordens & Besner, 1994; Plaut, 1997; Plaut & Shallice, 1993). These units are connected with each other and, through a learning process, these connections come to be weighted in a way that reflects the appropriate relationships among units. In these models, the semantic representations are tipically distributed, such that the meaning of each word is represented as a pattern of activation across a large set of units, with each unit corresponding to some aspect of its meaning[23]. Most accounts make the simplifying assumption that word meaning may be characterised as a single pattern of activation across these units. In other words, they assume that words have a single, well-defined meaning, and that there is a one-to-one mapping between the form of a word and its meaning. For ambiguous words, however, the process is more complex: because of their multiple meanings, these forms should involve the mapping of a single orthographic/phonological code onto two semantic codes. Many connectionist models of word recognition use strictly feed-forward connections, trained by a deterministic back-propagation learning algorithm (Rumelhart, Hinton, & Williams, 1986). These models cannot cope with the one-to-many mapping between form representations and semantics. Given such an ambiguity, the best solution that back-propagation can achieve is a compromise, where the semantic

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[22] They are so called because they rely on the idea that a single unit in memory represents a full meaning.

[23] Similarly, orthographic and phonological information of a word are represented as a specific activation pattern, which involves – respectively - orthographic and phonological units.

activation produced in response to the form of an ambiguous word is a blend between the two possible meanings (see Movellan & McClelland, 1993 for a detailed discussion of this issue). This blend is biased by the frequency of the different meanings, such that it most closely resembles the more frequent meaning. Such blends between unrelated meanings do not correspond to coherent meanings of real words.

As a result of the one-to-many connections, most PDP models predict a disadvantage both in the computation of output codes and in the semantic coding for ambiguous words (Seidenberg & McClelland, 1989). Joordens and Besner (1994) provided one of the first investigations of this issue by using a parallel distributed processing (PDP) model of semantic memory (Masson, 1991). The results of their simulation showed that the model was unsuccessful in activating an appropriate semantic pattern for each single meaning, instead of activating and ultimately settling into a "blend state" a combination of the semantics from the two meanings. When the simulations were successful (e.g., when the two meanings of the ambiguous word had quite different frequencies), there was no ambiguity effect. Joordens and Besner also reported that when the model by Hinton and Shallice (1991) was examined, performance was noticeably better for unambiguous words than for ambiguous words (in terms of error scores). The authors argued that the ambiguity advantage, if such an effect exists, presents a major challenge for PDP frameworks. Consistent with these predictions, an ambiguity disadvantage has been reported in word recognition tasks (e.g. Gottlob et al., 1999; Kawamoto & Zemblidge, 1992; Rodd et al., 2002; Seidenberg et al., 1984).

Despite the apparent natural tendency for such models to show an ambiguity disadvantage, there have been several attempts — in response to the earlier results — to show the reverse effect of ambiguity using PDP models.

It has been pointed out (Borowsky & Masson, 1996; Kawamoto, 1993; Kawamoto, Farrar, & Kello, 1994; Masson & Borowsky, 1995; Rueckl, 1995) that the argument of Joordens and Besner (1994) is valid only if semantic coding is assumed as necessary in word recognition tasks. If not, the prediction made by PDP models (ambiguous words should take longer to settle at the semantic level) might be irrelevant. As suggested by many authors (Balota, 1990; Balota & Chumbley, 1984, 1985; Besner, 1983; Besner & McCann, 1987; Hino & Lupker, 1996, 1998, 2000; McCann, Besner, & Davelaar, 1988; Pexman & Lupker, 1999; Seidenberg & McClelland, 1989), what is most important in the naming task is the phonological-coding process, which then drives the production of overt pronunciation responses, while in the lexical decision task the decision-making operation, based on the familiarity of the orthographic codes, is mandatory. Given these assumptions, in neither task the semantic coding would play a crucial role.

Relying on the assumption that lexical decisions are made on the basis of orthographic processing, Kawamoto (1993) and Kawamoto, Farrar, and Kello (1994) simulated ambiguity effects in lexical decision tasks using a PDP network model. In their simulations, the time (represented in terms of number of cycles) required to settle on an orthographic code was taken as a measure of lexical decision performance. In line with the mentioned functional structure of the network, for unambiguous words, a single orthographic pattern was associated with a single semantic pattern, whereas, for ambiguous words, a single orthographic pattern was associated with multiple semantic patterns. Since the one-to-many connections were somewhat difficult for the network to learn, the associations between orthographic and semantic units were weaker for ambiguous words than for unambiguous words. Thus, as suggested by Joordens and Besner (1994), the time to settle on a semantic code was, indeed, slower for ambiguous words than for unambiguous words. Although Kawamoto et al. failed to simulate an ambiguity advantage when the model was trained by the Hebbian learning algorithm[24], when it was trained by the least mean square error-correction learning algorithm[25], the

[24] The Hebbian learning algorithm belongs to the supervised learning class, in which synaptic values are modified on the basis of an association between input and output patterns. It is explicitly defined which kind of associations the network must learn.

[25] This algorithm was proposed by Widrow e Hoff (1960). It is based on the square error minimization principle through several iterations. Because of its implementation simplicity and robustness, it has been always one of the most pervasive adaptive algorithms.

weaker connections between orthographic and semantic units for ambiguous words were compensated for by the model, which established stronger connections among orthographic units for those words. That is, whereas the mean absolute values of the weights on the orthographic-to-semantic connections were smaller when the model was trained with ambiguous words rather than with unambiguous words, these values on orthographic-to orthographic connections were larger when the model was trained with ambiguous words rather than with unambiguous words. The stronger connections among orthographic units of ambiguous words determined a faster time to settle on an orthographic code for ambiguous than for unambiguous words. The authors suggested that ambiguity effects in lexical decision tasks are due to the faster orthographic processing for ambiguous words[26].

Borowsky and Masson (1996) proposed a different simulation of ambiguity effects using their PDP model. In their experiments, the authors used different types of nonwords in two lexical decision experiments: orthographically legal nonwords and orthographically illegal nonwords. Specifically, the ambiguity effect was significant only when legal nonwords were used[27]. According to Borowsky and Masson, the enhancement of ambiguity effects when a deeper level of processing is required for nonwords suggests that the locus of ambiguity effects is semantic rather than orthographic. As a result, the authors suggested that lexical decision making is based on computing the sum of energy at the orthographic and semantic levels. When the sum reaches a criterion value, a positive decision can be made. Indeed, ambiguous words, due to the semantic

[26] A similar assumption could be applied to the phonological connections, allowing the model to take into account the ambiguity advantage reported by Hino and Lupker (1996), Lichacz et al. (1999) and Rodd (2004) in naming tasks.

[27] Similarly, Pexman and Lupker (1999) examined ambiguity effects in two lexical decision experiments using legal nonwords and pseudohomophones. Pexman and Lupker reported that the ambiguity effect was larger with pseudohomophones than with legal nonwords.

activation they produce, reach this criterion faster in their model, allowing it to predict an ambiguity advantage[28].

In their computational model, Borowsky and Masson (1996) initially set semantic units to random states, which were then updated across cycles. Similar to Kawamoto et al. (1994), semantic units settled into a stable state faster for unambiguous words than for ambiguous words. However, when the sum of energy at the orthographic and semantic levels was measured, this value reached a criterion value faster for ambiguous words than for unambiguous words. The authors argued that this advantage arises because of a "proximity advantage". The network must move from the initial random state into a basin of attraction corresponding to the meaning of the word. For ambiguous words, there are multiple valid finishing states and, on average, the initial random state of the network is closer to one of these states than for an unambiguous word, where there is only one basin of attraction.

Hino & Lupker (1996) proposed a third account of the ambiguity advantage, called the "feedback account". They used a PDP framework, although its principles could also be applied to localist frameworks, like the dual-route model (Coltheart, Rastle, Perry, Langdon and Ziegler, 2001). After Kawamoto et al. (1994) and, to some extent, Borowsky and Masson (1996), Hino and Lupker (1996) assumed that lexical decisions are based primarily on the orthographic familiarity of stimuli. In contrast, in the naming task, the phonological code is assumed to play a central role, because pronunciation is required. Hino and Lupker (1996) suggested that ambiguity effects in lexical decision are tied to feedback activation from the semantic to the orthographic level, whereas ambiguity effects in naming are due to feedback activation from the semantic to the phonological level. Accordingly, since ambiguous words activate multiple semantic codes, ambiguous words produce a greater amount of semantic activation than unambiguous words. Thus, the amount of feedback activation from the semantic level to the orthographic or phonological level

[28] However, the model does not predict an ambiguity advantage in naming (i.e., phonological units are activated at the same rate for both ambiguous and unambiguous words). This is intentional. As noted, Borowsky and Masson did not observe an ambiguity advantage in naming.

is greater for ambiguous words. Thus, both the orthographic processing required in making lexical decisions and the phonological coding required in naming are more supported for ambiguous than for unambiguous words by the semantic feedback. The main requirement of this account is that the system is highly interactive: ambiguity effects are due to feedback activation from semantics to orthography or phonology.

The different account of Kawamoto et al. (1994) was based on the strength of connections at the orthographic level. Although their model involves semantic-feedback connections to orthographic units, semantic feedback activation was not the source of ambiguity effects. Even in contrast with Hino and Lupker (1996), Borowsky and Masson (1996) suggested that ambiguity effects are due to a faster decrease in energy values at the orthographic and semantic levels because of the expected proximity of at least one semantic representation for ambiguous words.

At present, among the mentioned accounts, the feedback account appears to be the most reliable one. The principle that feedback plays a major role in word recognition (see Balota, Ferraro & Conner, 1991) has a considerable support: it provides a ready explanation of the homophone disadvantage in lexical decision (e.g., Pexman, Lupker & Jared, 2001), the synonym disadvantage in lexical decision (Hino, Lupker & Pexman, 2002; Pecher, 2001) and the lexical decision and naming advantages for words with larger numbers of semantic features (Pexman, Lupker & Hino, 2002).

3.5 Ambiguity effects in semantic categorization tasks

In both localist and connectionist approach, the general assumption is that in word recognition tasks responses can be accomplished without completing semantic processing. Ambiguity may produce an advantage because the activation of a blend state – among multiple meanings - is enough to access the word. In semantically-based tasks, the process is quite different: the responses would be mainly based on the results of semantic processing. Thus, task performance would not be sensitive to feedback from the semantic level to other levels (as predicted by Hino &

Lupker, 1996). Rather, task performances should be more sensitive to the speed of meaning determination, that is, the speed of settling at the semantic level. That speed would be most affected by the nature of the relationships from orthography to semantics. Therefore, if a task requires meaning determination, as Joordens and Besner (1994) have argued, an ambiguity disadvantage should be observed because of the one-to-many feedforward mappings between orthography and semantics. Three types of experimental paradigms have been used to address this issue.

The first paradigm involves a standard reading task. Eye movements are monitored while subjects read sentences containing either ambiguous or unambiguous words. Using neutral sentence contexts (e.g., *He thought that the punch/cider was a little sour*) Rayner and Duffy (1986) found that gaze durations on both the target word and the following words were longer when the target word was ambiguous (i.e., *punch* versus *cider*). However, this difference was only observed if the two meanings of the target word were approximately balanced. The conclusion, therefore, is that there is an ambiguity disadvantage when reading for meaning.

The second experimental paradigm is the association judgment task. In this task, subjects are asked to decide whether the two words they see (e.g., *bat - vampire*) are semantically related. Using sequential presentations with the ambiguous word (e.g., *bat*) as either the first or the second word, Gottlob et al. (1999) found that it took longer to determine that two words were related when one of them was ambiguous. Similar results were reported by Piercey & Joordens (2001) and interpreted as evidence that, when the appropriate meaning of ambiguous words must be chosen, a processing cost is required.

Unfortunately, some of the results in this task are open to alternative interpretations. For instance, when the ambiguous words were presented first and the stimulus onset asynchrony was long (as it was in Piercey & Joordens, 2000, and in Experiment 2 of Gottlob et al., 1999), participants had sufficient time to select and focus on one of the multiple meanings of the ambiguous word, before the second stimulus (unambiguous) appeared. Thus, the delay in responding to the second word may be due to the inconsistent meaning of the ambiguous word previously activated.

When the ambiguous word was presented second, as it was in Gottlob et al. (1999, Experiment 3), a slightly different problem arose. The early activation of two meanings for *bat* would presumably cause a response conflict. The animal meaning of *bat* suggests that it is related to *vampire*; the baseball meaning suggests that a negative response is required. In all cases, an ambiguity disadvantage should emerge, not necessarily because of competition during meaning activation, rather because of problems created during decision making.

There is also a second interpretation problem. To create the ambiguous word trials, each ambiguous word was paired with a word that was related to only one meaning. Thus, it is possible that the ambiguity disadvantage did not arise for the meaning selection process, but because the other activated meaning of the ambiguous words produced a bias toward a "no" response. That is, it is possible that the ambiguity disadvantage observed in the association judgment tasks was not due to the meaning determination process but, rather, to the decision-making process.

With respect to the relatedness judgment task, Pexman, Hino and Lupker (2004) demonstrated that the ambiguity disadvantage observed in that task might be due to a response bias. Using both sequential and simultaneous presentations of word pairs, Pexman et al. (2004) replicated the ambiguity disadvantage on positive trials (Gottlob et al., 1999; Piercey & Joordens, 2001). However, they did not find evidence of a disadvantage effect on negative trials (e.g., *bat - door*). The important aspect is that ambiguous words do not create a response conflict on negative trials, because both meanings are unrelated to the paired word. If the ambiguity disadvantage was due to difficulty in activating the meaning, there should has been a disadvantage effect on these trials as well.

A similar argument can be made to explain the ambiguity disadvantage in on-line reading tasks, where the reader must select the intended meaning of the ambiguous word in order to understand the passage, (e.g., Duffy et al., 1988; Rayner & Duffy, 1986). In contrast with the explanation provided by PDP-based accounts, these results suggest that the speed of semantic coding does not depend on the nature of orthography-to-semantics relationships.

The third paradigm is the semantic categorization task, where participants are required to determine whether a meaning of a word falls into a given semantic category. Hino et al. (2002) reported that it was more difficult to categorize ambiguous vs. unambiguous words as being non-living things in a two-choice (living – non-living) task. In their experiments, the authors selected only ambiguous words whose all meanings belonged to the same semantic category, in order to address the response-bias problem. When these same words were used in a lexical decision experiment, the typical ambiguity advantage was observed.

Previously, Forster (1999) had not found ambiguity effects in a different semantic categorization task (animal-non animal). More recently, Hino et al. (2005) re-examined this issue and discovered that there is no ambiguity disadvantage when the task involves small, well-defined categories (e.g., vegetables or animals). Even when using larger categories (e.g., living things), the disadvantage emerges only on homonymous words (with two unrelated meanings). If the ambiguity disadvantage was due to difficulties during the meaning activation process, it should arise in any task requiring semantic processing. The fact that it had such a limited role is more consistent with a decision-making/meaning selection explanation. That is, only when two unrelated meanings become activated in a complicated decision-making process (e.g., *bank* - is it living?) a delay occurs because each meaning has to be thoroughly considered. When the multiple meanings are more closely related or when the categorization task is easier (e.g., animal-non animal), a more parallel analysis of the multiple meanings can be done.

3.6 Meaning/sense distinction: looking for processing implications

One possible explanation of controversial ambiguity effects reported in word processing literature could be that most studies did not distinguish among different types of lexical ambiguity, by treating, lexical ambiguity as an all-or-nothing phenomenon. The concept of ambiguity is more articulated in the linguistic literature, where a clear distinction is made between homonymous words, that is, words that have multiple unrelated meanings, and polysemous words with multiple senses based on the same original meaning (see Chapter 1 for a discussion).

Although polysemy is more frequent in language, most psycholinguistic and neurolinguistic studies to date have focused on homonymy. With respect to homonymy, most models agree that multiple, unrelated meanings are represented separately in the mental lexicon. On the contrary, the representation of polysemous words has been quite controversial. The question that recent studies addressed is how the multiple, closely related senses of polysemous words are represented and activated in the mental lexicon. Are the multiple related senses of polysemous words processed just like the multiple unrelated meanings of homonymous words or do they employ different processes? Understanding whether this linguistic distinction is also psychologically real appears to be crucial.

A number of recent studies, focusing on the semantics of ambiguous words, provided evidence for differences in processing between homonymy and polysemy. For example, in an eye-movement study, Frazier and Rayner (1990) compared the reading of homonymous words with the reading of polysemous words, presented in context. When disambiguating information preceded the target word, Frazier and Rayner (1990) found that fixation times were longer for all sentences with ambiguous words. However, when the disambiguating information followed the target word, reading times for the disambiguating region were longer for homonymous words than for unambiguous words, probably due to the cost of reanalysis when the assignment of meaning — possibly due to frequency — was inconsistent with the following context. No such differences were found for polysemous words, suggesting that there was no reanalysis. Based on their results, Frazier and Rayner (1990) suggested that, in the case of polysemous words, since the multiple senses are not mutually exclusive, immediate selection of one sense may not be necessary.

Further evidence for a facilitation due to the inter-relatedness of multiple senses on the processing of polysemous words comes from a study by Williams (1992). In a relatedness judgement task, as well as in a lexical decision priming task, Williams examined whether the processing patterns observed for homonymous words were replicated for polysemous words. He visually presented polysemous adjectives (e.g., ‘‘dirty’’, meaning both ‘‘soiled’’ and ‘‘obscene’’) within a sentence context, followed by targets which were related either to the central or the secondary sense of the adjective. Williams (1992) found priming effects even when targets were related to the contextually inappropriate sense of polysemous words. He obtained this effect at all ISIs (0, 500, 850 ms); however, the effect was stronger for the basic sense of the adjectives. Similar results were reported in a relatedness judgement task. Williams (1992) compared his findings to those of previous priming experiments with homonymous words (Seidenberg et al., 1982; Swinney, 1979) and concluded that the multiple senses of polysemous words are interrelated, differently from homonymous words. For these latter words there might be initial multiple meaning activation, but the activation of contextually irrelevant meanings is short-lived.

Other studies - either intentionally or unintentionally - investigated processing differences between homonymy and polysemy in word recognition tasks. For instance, Jastrzembski (1981) found that words with multiple meanings associated with a single derivation (same etymology) were accessed faster than words with an equal number of meanings that were associated with multiple derivations.

Another attempt to directly assess the issue of the psychological reality of the meaning/sense distinction was provided by Azuma and Van Orden (1997). In their lexical decision experiments, they used ambiguous words for the real-word condition, and manipulated the degree of “relatedness-of-meanings” (high or low) and “number-of-meanings” (many or few). For the non-word condition, in the first experiment they used legal non-words, while in the second experiment they used pseudohomophones. Following the argument of Gernsbacher (1984) that the best way to know what is going on in processing is to ask subjects, Azuma and Van Orden obtained number-of-meaning and relatedness-of-meaning measures by asking subjects to rate words on both dimensions. To determine the number of meanings, they used the same procedure of Millis and Button (1989): a count of how many dictionary meanings were listed by at least one subject was made. To determine the relatedness of meanings, they selected the dominant meaning of each word and asked subjects to rate how strongly it was related to each of the subordinate meanings (on a seven point scale). They then calculated the average of these ratings.

Using standard nonwords (e.g., *prane*) Azuma and Van Orden did not find effects of number-of-meanings and relatedness. Using pseudohomophones (non-words that when pronounced sound like word, e.g., *brane*), they got a large interaction. Within ambiguous words, those with few unrelated meanings had the slowest reaction times. The results were interpreted as depending on relatedness rather than number of meanings[29]. Azuma and Van Orden also underlined the existence of a "polysemy effect" and a possible cognitive distinction between ambiguous words having high and low relatedness in meanings.

In spite of its methodological limitations, the study of Azuma and Van Orden (1996) focused on the important role played by the nature of non-words used in word recognition tasks. Indeed, the use of illegal non-words (e.g., *prvnt*) unavoidably reduces overall latencies and shrinks the size of any effect (Borowsky & Masson, 1996; Stone & Van Orden, 1993). On the contrary, when pseudohomophones are used, latencies are longer and the impact of variables on processing often increases.

Azuma and Van Orden (1997) suggested that pseudohomophones do more than simply complicating the task. Reliably, they get subjects to attend more to semantic information which can, potentially, provide a better window on the nature of semantic representations.

Other studies explicitly comparing processing patterns of homonymous and polysemous words were carried out by Klein and Murphy (2001; 2002). They first used a "sensicality judgment task": word pairs (e.g., *yellow lecture*) were presented, and subjects had to decide whether the word

[29] They felt that the way they measured relatedness (ratings of how related each subordinate meaning is to the dominant meaning) did not adequately capture the relatedness among meanings of multiple-meaning words (because the relatedness among subordinate meanings was not considered). Thus, the data from the few meaning conditions, showing a relatedness advantage, should be taken more seriously than the data from the multiple-meaning condition.

combination made sense. In all the sequential trials the second word was repeated (e.g., *daily paper* - *wrapping paper*). On half of these trials, the first word in the two pairs evoked the same sense of the second word (e.g., *daily paper – liberal paper*). On the other half, it evoked a different sense (e.g., *wrapping paper* - *liberal paper*). The idea was that if all the senses of a concept are stored together in memory, both *daily paper* and *wrapping paper* should activate the semantic information necessary to process *liberal paper*. If the senses of *paper* were stored separately, however, pairs evoking the same sense would have acted more strongly as "primes". For the "same sense" primes, they found a large advantage, perfectly comparable to the advantage for the "same meaning" primes when homonyms were used (e.g., *commercial bank* - *savings bank* versus *creek bank – savings bank*). They interpreted these findings as evidence for the similar processing between homonymous and polysemous words. "The main empirical result is the finding that different senses have little functional overlap - about the same as the unrelated meanings of homonyms" (p.277).

Klein and Murphy (2002) obtained similar results in a similarity judgment task. In this task, participants had to decide which of two word pairs was most similar to a target phrase (e.g., *daily paper*). One phrase used the same second word as the target phrase, but had a first word that evoked a different sense for the second word (e.g., *shredded paper*). The other phrase did not repeat any word, but was semantically related to the target phrase (e.g., *evening news*). Subjects rarely chose phrases that shared a word with the target phrase (less than 20%). However, this happened slightly more often in the polysemous word condition than in the homonym condition (e.g. target: *national bank*, options: *river bank* and *checking account*). Klein and Murphy concluded that "different senses of a word are probably related but are not generally similar". Generally speaking, what Klein and Murphy (2001; 2002) reported was an absence of processing differences between homonymous and polysemous words. However, it could be assumed that their findings depend on the specific task, which requires a particular sense of a word being retrieved.

Alternative results were obtained by Rodd, Gaskell, and Marslen-Wilson (2002), in visual and auditory simple lexical decision tasks where ambiguous with many or few senses and unambiguous words were compared. Rodd et al. (2002) used the Wordsmyth dictionary, rather than subjective ratings, to determine how many unrelated meanings and how many senses each of their words had. They manipulated number of meanings (one or two) and number of senses (few or many) while using pseudohomophones as their nonwords. Rodd et al. observed a significant number-of-senses advantage and a nonsignificant number-of-meanings disadvantage. In the auditory lexical decision task, using most of the same words, Rodd et al. obtained both significant advantage and disadvantage effects.

In the light of these results, they concluded that there is a processing advantage only for polysemous words, while multiple meanings determine the types of problem predicted by PDP models. The most interesting and novel aspect of these results is, of course, the ambiguity disadvantage reported for homonymous words. More recently, Beretta, Fiorentino and Peoppel (2005) using the same stimuli of Rodd et al., have reported a significant number-of-meanings disadvantage.

Relatedness effects were also found by Klepousniotou (2002) and Klepousniotou & Baum (2007), who focused also on a further distinction of polysemy, based on theoretical linguistics, into two types which are basically motivated by two distinct figures of speech, namely metaphor and metonymy (Apresjan, 1974). The study of Klepousniotou (2002) was the first to exploit the distinction within polysemy and also directly compared homonymous and polysemous (both metaphorical and metonymic) words in context, investigating their processing and representation patterns. The three types of ambiguous words - homonymous words (e.g., *bank*), polysemous words with metaphorical extensions (e.g., *star*), and polysemous words with metonymic extensions (e.g., *chicken*) - were used in a cross-modal lexical decision task. Sentences biasing toward either the dominant or the subordinate meaning/sense of ambiguous words were auditorily presented. Immediately after, a target was visually presented for lexical decision. Targets were either homonymous or polysemous words, unrelated control words or non-words. Differences were found among the three types of ambiguous words. In particular, polysemous words with metonymic extensions showed stronger facilitation and were processed significantly faster than homonymous words, while polysemous words with metaphorical extensions fell somewhere between metonymy and homonymy and did not differ statistically from each other. Klepousniotou (2002) suggested that the time differences indicate representational differences, depending on the type of ambiguity the words exhibit. Homonymous words show longer reaction times, possibly because their multiple unrelated meanings are competing, thus leading to a time-processing cost. Polysemous words, and in particular metonymies, are processed significantly faster presumably because there is no meaning competition. This findings indicate that, for metonymous words, there is only a single mental representation specified for the basic sense of the word, which assigns a general semantic value. In this investigation, the processing advantage was confined to ambiguous words with multiple closely related senses (i.e., metonymically polysemous words).

Klepousniotou & Baum (2007) investigated the effects of multiple unrelated meanings versus multiple related senses in two simple auditory and visual lexical decision tasks. The pattern of results is similar to Klepousniotou's (2002): only polysemous words are processed faster than unambiguous control words matched for frequency. Nevertheless, differences emerge between metonymy and metaphor. In particular, metonymous words show a more robust processing advantage than unambiguous control words, compared to metaphorical words. Although metaphorical senses are still related in meaning, they are less sensitive to processing facilitation effects, as they have a tendency to be more lexicalized and ''irregular'' than metonymic senses. Finally, homonymous words do not exhibit any processing advantage relative to unambiguous control words. The results are consistent with the hypothesis that only ''sense-relatedness'' produces the processing advantage observed in lexical decision studies on ambiguous words.

3.7 Electrophysiological evidence for the distinction between homonymy and polysemy

Many lexical ambiguity studies that used electroencephalography (EEG) and measured event-related potentials (ERPs) - in particular the N400 component that marks lexical-semantic processing - have focused on homonymy. These studies often investigated the processing of dominant-related and subordinate-related targets in priming experiments (e.g., Atchley & Kwasny, 2003; Chwilla & Kolk, 2003; Titone & Salisbury, 2004).

More recently, a MEG study (Beretta, Fiorentino, and Poeppel, 2005) investigated the processing of lexical ambiguity. The MEG component this investigation focused on is the M350, which emerges approximately 350 ms after the onset of the critical stimulus. The M350 component is considered equivalent to the N400 ERP component, and has been shown to mark lexical activation and semantic processing. Using MEG and a visual lexical decision task, Beretta et al. (2005) found that words with more than one meaning were accessed more slowly than words with a single meaning (they elicited later M350 peak latencies and slower reaction times). In addition, words with many senses were accessed faster than words with few senses (they elicited earlier M350 peak latencies and faster reaction times). However, as for the findings of Rodd et al. (2002), the interaction between relatedness in meaning and number of senses was not significant. Therefore, it is still not clear from these results whether the processing advantage, either at a behavioural or neuronal level, is confined only to what the authors call ‘‘unambiguous words with multiple related senses’’ (i.e., polysemous words).

The other MEG study, conducted by Pylkkänen, Llinas, & Murphy (2006), used the same stimuli of Klein and Murphy (2001) in an acceptability judgement task. Two-word phrases of homonymous and polysemous words were preceded either by a related prime phrase biasing toward to the opposite meaning of the ambiguous word (e.g., *river bank – savings bank; lined paper – liberal paper*) or by an unrelated prime phrase (e.g., *salty dish – savings bank; military post – liberal paper*). In order to investigate whether the processing of polysemy involves identity or just formal and semantic similarity, they compared these phrases to phrases that were semantically related and were primed either by a related prime (e.g., *lined paper – monthly magazine*) or by an unrelated prime (e.g., *clock tick – monthly magazine*). The behavioural data of Pylkkänen et al. (2006) replicated those of Klein and Murphy (2001); namely, no difference was found between homonymy and polysemy, as in both cases related targets were responded to faster than unrelated targets. Interestingly though, for homonymous words, the MEG data (focusing again on the M350 component) showed that related targets elicit later M350 peak latencies than unrelated targets in the left hemisphere (LH), suggesting inhibition effects. On the other hand, for semantic targets, there was facilitation for related pairs: the M350 in the LH peaked earlier than for the unrelated pairs. Polysemous words behaved similar to semantic targets; namely, the M350 peaked earlier for the related targets than for unrelated targets, supporting the single lexical entry hypothesis.

Finally, a EEG study carried out by Klepousniotou, Pike, Steinhauer, & Gracco (2012) replicated the behavioural findings of Klepousniotou (2002). In this study, event-related potentials (ERPs) were used to investigate the time-course of meaning activation of different types of ambiguous words. Unbalanced homonymous, balanced homonymous, metaphorically polysemous and metonymically polysemous words were used in a visual single-word priming delayed lexical decision task. The theoretical distinction between homonymy and polysemy was reflected in the N400 component. Homonymous words (balanced and unbalanced) showed effects of dominance/frequency with reduced N400 effects predominantly observed for dominant meanings. Polysemous words (metaphors and metonymies) showed effects of core meaning representation with reduced N400 effects observed both for dominant and subordinate meanings. Furthermore, the metaphor/metonymy partition within polysemy was supported by the electrophysiological data.

3.8 Modelling the relatedness-of-meanings (ROM) effects

The majority of studies which have addressed the relatedness-of-meanings effects seem to provide support to theoretically motivated differentiation of lexical ambiguity into homonymy and polysemy. In order to account for the processing differences between words with multiple unrelated meanings and words with multiple related senses, Rodd, Gaskell, and Marslen-Wilson (2004) proposed a PDP model. They suggested that words with unrelated meanings form deep, narrow attractor basins that are separately stored in the mental lexicon, while words with related senses form shallow, broad basins which are represented within the same region of semantic space. The ambiguity disadvantage emerges because homonymous words have separate meanings corresponding to separate attractor basins in different regions of semantic space. In the early stages of the network settling, a blend of multiple meanings of homonymous words is activated. Gradually, the network moves away from the blend state and settles in one of the different meanings. This process of moving away from a blend state makes homonymous words harder to recognize. In contrast, the different possible semantic representations of words with multiple senses do not correspond to separate regions in semantic space; the distributed semantic representations of different senses of these words are highly overlapping, correspond to neighbouring points in semantic space, and result in faster activation of semantic features, producing a processing advantage. Within this framework, Rodd et al. were able to partially simulate the results of their behavioural study, with an advantage for words with many senses and a disadvantage for words with many meanings.

Rodd et al. (2004) cautioned that their simulations predict that the sense benefit is restricted to tasks where the activation of any semantic information is sufficient to support performance. However, in tasks that require a particular sense of a word to be retrieved, it is possible that the different word senses compete with each other and produce a sense disadvantage (e.g., Klein & Murphy, 2001).

The majority of studies on homonymy/polysemy distinction seem to converge on the idea that the key factor of ambiguity advantage effects is the sense relatedness. Within a PDP framework, a reasonable assumption is that the semantic representations for related meanings share semantic features. If so, the orthographic-to-semantic mappings would be more consistent (i.e., those mappings may produce less competition during the settling process) for ambiguous words with related meanings than for ambiguous words with unrelated meanings. As a result, if the speed of semantic coding is modulated by the nature of orthographic-to-semantic mappings, semantic coding should be faster for ambiguous words with related meanings than for ambiguous words with unrelated meanings, producing a relatedness advantage in semantically-based tasks. The further implication, of course, is that any ambiguity disadvantage (in comparison to unambiguous words) should be larger for ambiguous words with unrelated meanings than for ambiguous words with related meanings.

The implications of ROM for the lexical decision task, however, are somewhat unclear. If speakers had to rely on semantic coding to make lexical decisions, a relatedness advantage would be expected (see Azuma & Van Orden, 1997). Nevertheless, if lexical decisions were assumed to be made on the basis of orthographic codes, predictions would be not so obvious. For example, assuming that lexical decision performance is affected by semantic feedback to the orthographic level, Locker et al. (2003) suggested that the amount of semantic feedback could be modulated by the processing competition at the semantic level. Because stronger competition is expected at the semantic level for homonymous words, less semantic feedback might be expected for them. If so, a relatedness advantage would be predicted.

Wery similar accounts (e.g., Hino et al., 2002; Pexman et al., 2004) could also make the opposite prediction: if related meanings share semantic features, the amount of semantic activation could actually be greater for homonymous words than for polysemous words since more semantic units (representing semantic features) would be activated by unrelated meanings. As such, if there were any relatedness effect at all in the lexical decision task, one would expect a relatedness disadvantage, rather than a relatedness advantage.

3.9 CONCLUDING REMARKS

In this chapter I reported the most relevant behavioural, computational and physiological attempts at understanding the effect of lexical ambiguity during lexical access.

Summing up:

- Most research comparing the processing of ambiguous and unambiguous words in isolation reported faster reaction times for ambiguous words than for unambiguous words in naming and visual lexical decision tasks, known as the ‘‘ambiguity advantage’’ effect (AAE)
- While lexical ambiguity produces an advantage in word recognition tasks, it causes a time-processing cost in those tasks which require a complete semantic access and meaning decision process (e.g., sentence reading, semantic categorization).
- Many attempts to replicate the AAE, however, either failed to observe any effect or reported inhibitory effects. In spite of the great deal of investigations over the past 40 years, the existence of processing differences between ambiguous and unambiguous words is still controversial.
- The challenge of explaining the ambiguity effects in word processing provided a large impetus in the development of both localist and computational models about how semantic information is lexically stored and accessed.
- A great deal of evidence suggested that there are different implications for the processing of homonymy and polysemy: the ambiguity advantage effect reported in word recognition literature seems to be due only to sense relatedness.
- Reviewing the literature on the topic, it emerges that most studies have been inconsistent in several methodological aspects (meaning counting procedure, nonwords type, meaning relatedness, task

type, ecc.), which may explain why the patterns of results are strongly heterogeneous.


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CHAPTER 4

REVISITING HOMONYMY EFFECTS IN VISUAL WORD RECOGNITION

4.1 Introduction

The general aim of the experiments described in this chapter was to investigate the factors which affect the lexical processing of homonymous words in single word recognition. Considering lexical ambiguity as a unique, homogeneous macro-phenomenon could be confounding, as actually multiple variables seem to play a crucial role in determining different - and sometimes contradictory - results. The literature on the topic shows that most studies which have addressed the issue of differences in lexical representation and processing between ambiguous and unambiguous words reported heterogeneous patterns of results. One possible explanation for such discrepancies could be that there was no consistency in several methodological aspects.
In order to clarify the levels of meanings investigated, issues such as how the meanings were collected, the type of ambiguous words under investigation, the type of non-words used in lexical decisions, the grammatical class of the stimuli, and the experimental paradigms adopted should be taken into consideration. In the following, I discuss each of these factors.

Meaning collection procedures. Past research has been often inconsistent in calculating word meanings. Some researchers (Gernsbacher, 1984; Jastrzembski, 1981; Jastrzembski & Stanners, 1975) relied on listing meanings in dictionaries. The dictionary representation of meanings not only varies from dictionary to dictionary, but also provides meanings that are no longer familiar to language users. Most other research gathered meanings from subjects (Azuma & Van Orden, 1997; Borowsky & Masson, 1996; Clark, 1973; Forster & Bednall, 1976; Gernsbacher, 1984; Hino & Lupker, 1996; Kellas et al., 1988; Millis & Button, 1989; Rubenstein et al., 1971). Resorting to subjects for their linguistic knowledge may sound more relevant to the purpose of examining their semantic knowledge, but researchers still differed as to the way of calculating the collected meanings. Some of them calculated the first meanings subjects provided, others the total number of meanings, still others the average number of meanings. Some referred to dictionaries for meaning delimitation; others determined the numbers of meanings subjects provided by intuition. All these differences make past research rather inconsistent in talking about word meaning and ambiguity effects.

Ambiguity status. In Chapter 3, it was showed that several works did not take into consideration different types of lexical ambiguity. Meaning relatedness is a semantic dimension that may confound the ambiguity advantage effect, but little previous research has considered it. For example, Jastrzembski (1982) considered the etymological derivations and clustered the meanings of his stimuli. Azuma and Van Orden (1997) collected the rating of semantic relatedness from subjects. More recent works (Beretta, Fiorentino, & Peoppel, 2005; Klepousniotou, 2002; Klepousniotou & Baum, 2007; Rodd, Gaskell, & Marslen-Wilson, 2002) found significant processing differences between homonymous and polysemous word in word recognition tasks, due to the fact that these forms are differently stored in mental lexicon. Other experiments did not systematically controll stimuli for this variable.

Experimental paradigms. Only recently researchers have started to interpret the mixed advantage and disadvantage results of lexical ambiguity in terms of the different experimental paradigms adopted (Hino et al., 2002, 2006; Piercey & Joordens 2000; Siakaluk et al., 2007). An ambiguity advantage was obtained when the task only required the activation of any meaning associated with a word (e.g., lexical decision tasks). When a particular meaning had to be selected in a sentential context (such as in eye-tracking sentence comprehension tasks) or for semantic judgments (e.g., semantic categorization tasks and semantic relation tasks), then an ambiguity disadvantage was obtained. The facilitatory and inhibitory effects based on semantic ambiguity demonstrated that different degrees of semantic access were required to perform different experimental tasks. In order to accommodate the facilitatory and inhibitory results, it seems crucial to consider the nature of different experimental paradigms and the different levels of lexical access involved.

Non-word type in lexical decision tasks. Research in the past has been inconsistent as to non-words used in lexical decision tasks. Illegal non-words (i.e., unpronounceable non-words like BLFE), legal non-words (i.e., pronounceable non-words like BELF), or pseudohomophones (i.e., non-words that have the same pronunciations as real words, e.g., BEAF) were used. Different types of non-words influence the strategy subjects apply in doing the task, and thus affect reaction times. For example, the use of non-words that are more word-like ensures that participants actually use their lexical semantic knowledge in making lexical decisions, rather than relying on superficial orthographic or morphological features. Borowsky and Masson (1996) found an ambiguity advantage in recognition of real words when they used legal non-words, but not when they used illegal non-words. Azuma and van Orden (1997) found ambiguity advantage when they used pseudohomophones, but not when they used legal non-words. Pseudohomophones, as the most word-like non-words, have therefore been adopted in recent studies (e.g., Azuma & van Orden 1997; Rodd et al., 2002).

Meaning frequency effects. In visual word recognition literature one of the most robust findings is the so-called frequency effect: words which appear more often in printed language are easier to recognize than words which appear less frequently (for a review, see Grainger, 1990). Thus, models of visual word recognition all incorporate this effect as a part of the word recognition process. For example, serial search (Forster, 1976), or verification models (Becker, 1976; Paap, Newsome, McDonald, & Schvaneveldt, 1982) explain the word frequency effect in terms of a frequency-ordered serial comparison stage occurring in visual word recognition. Other models explain the effect in terms of either variations in recognition threshold (Morton, 1970) or variations in the resting level activation of word detectors (McClelland & Rumelhart, 1981).

As far as ambiguous words are concerned, two types of word frequency should be taken into consideration: firstly, the total frequency, which refers to how many times a word occurs in a printed language, independently from the specific meaning it assumes; secondly, the relative frequency of the single meanings, which means counting the number of occurrences in one of the meanings. In this way, it is also possible to distinguish between ambiguous words with two frequency-equal meanings (balanced) and ambiguous words with one more frequent meaning (unbalanced). Evidence from eye-movement studies showed how meaning frequency effects play a role in processing ambiguous words. As reported in Chapter 2, fixation times are often longer when context supports the subordinate meaning of an unbalanced ambiguous word compared to all the other conditions. Furthermore, when the context is neutral with regard to the different meanings of an equi-balanced ambiguous word, readers take longer than on an unbalanced ambiguous word or an unambiguous control word (Binder, 2003; Binder & Rayner, 1998; Duffy, Morris, & Rayner, 1988; Pacht & Rayner, 1993; Rayner, Pacht, & Duffy, 1994). This has been explained in terms of competition between the two equally available meanings of the balanced word (e.g., Duffy et al., 1988). These results provide empirical support for perspectives like the *reordered access model* (Duffy et al., 1988) and the *integration model* (Rayner & Frazier, 1989), which predict that the access to the meanings of ambiguous words is guided both by sentence context and frequency dominance.

However, in single word recognition tasks, where the general aim is to compare lexical processing of ambiguous and unambiguous words out of context, in few studies stimuli were controlled for meaning frequency dominance. For example, Rubenstein et al. (1971) reported that the ambiguity advantage was restricted to ambiguous words with two equi-probable meanings. Nevertheless, other variables, such as grammatical class and meaning relatedness, were not strictly controlled.

As it was shown by the literature on ambiguity resolution process, it is reasonable to assume differences between balanced and unbalanced ambiguous words also in lexical processing, given the different degree of competition between two alternative representations. In the case of ambiguous words with frequency-equal meanings, the multiple representations are expected to have the same activation strength and to compete with each other until the word has been recognized; conversely, in the case of unbalanced ambiguous words the dominant meaning will always “win” without difficulties.

Parts of speech. The syntactic category of the stimuli is a factor that has not been taken into account in most previous studies on lexical processing of ambiguous words (e.g., Azuma & van Orden 1997; Klepousniotou, 2002; Millis & Button, 1989; Rodd et al., 2002). Words across different syntactic categories were adopted as experimental materials. However, previous research showed that words of different syntactic categories, particularly nouns and verbs, involve distinct psychological processes (Chiarello et al., 1999; Deutsch et al., 1998; Druks, 2002; Kim & Thompson, 2000; Marinellie & Johnson, 2004; Sereno & Jongman, 1997; Shapiro & Caramazza, 2003; Spenney & Haynes, 1989; Tyler et al., 2004). The distinction between nouns and verbs is a central property of human language, beginning with acquisition, reported in normal usage, and often shown in language breakdown (Koenig & Lehmann, 1996). Verbs have relational meaning, while nouns have meanings as referents or objects (Gentner, 1978; Reyna, 1987). Berndt, Mitchum, Haendiges, and Sandson (1997a) found that verbs are acquired later, are more difficult to process, have a greater range of meanings and are more difficult to understand than nouns. Nouns are processed more quickly (Gomes, Ritter, Tartter, Vaughan, & Rosen, 1997). Verbs are more complex syntactically and morphologically (Bates, Chen, Tzeng, Li, & Opie, 1991). Neurological studies report that there are different anatomical substrates for nouns and for verbs (Daniele, Giustolisi, Silveri, Colosimo, & Gainotti, 1994; Gomes et al., 1997; Kersten, 1998; Koenig & Lehmann, 1996; Pulvermuller et al., 1996; Silveri, Perri, & Cappa, 2003). Daniele et al. (1994) claimed that there are separate neural systems for the different categories, the temporal lobe for nouns, the frontal lobe for verbs. Warrington and McCarthy (1987) suggested that action verbs are processed in the motor channel. Damasio and Tranel (1993) proposed an interactive network rather than a fixed neural site for word forms. Experiments using event-related potentials (ERPs) suggested that different neural populations represent different word classes (Koenig & Lehmann, 1996). Pulvermuller, Preissi, Lutzenberger, and Birbaumer (1996) found stronger 30Hz activity elicited by verbs over the motor cortices, while stronger responses were elicited by nouns at sites in the occipital lobes over visual cortices. Other studies (Hernandez, Dapretto, Mazziotta, & Bookheimer, 2001; Soros, Cornelissen, Laine, & Salmelen, 2003; Tyler, Russel, Fadili, & Moss, 2001) did not report an effect of word-class in healthy speakers using functional neuroimaging. Focal brain damage has produced selective deficits in either nouns (Wernicke's aphasia, anomia) or verbs (Broca's aphasia) (Bates et al., 1991; Berndt et al., 1997a, Berndt, Haendiges, Mitchum, & Sandson, 1997b; Lapointe, 1985; Miceli, Silveri, Villa, & Caramazza, 1984; Miceli, Silveri, Noncentini, & Caramazza, 1988; Silveri et al., 2003; Zingeser & Berndt, 1988, 1990). Bates et al. (1991) found a double-dissociation between object and action naming in Chinese Broca's versus Wernicke's patients. In Daniele et al. (1994), non-fluent patients were accurate in noun production, while fluent noun-impaired patients had trouble with both nouns and verbs. Damasio and Tranel (1993) found that verb-impaired patients had left premotor cortex lesions; noun-impaired patients had damage to the left anterior and middle temporal lobe. Pulvermuller et al. (1996) suggested that lesions in the frontal lobe produce problems with verbs whereas lesions in the inferior temporal lobe produce problems with nouns. In Caramazza and Hillis' (1991) patients, errors were not uniformly distributed across nouns and verbs, and reflected modality (writing versus speaking) as well as grammatical class. In that and other accounts by the same authors (Hillis & Caramazza, 1991; 1995), a patient retrieved the noun but not the verb meanings in written form, and showed the reverse impairment in speech, suggesting "that grammatical category information is represented separately and redundantly in each modality-specific lexical system." (Caramazza & Hillis, 1991, p. 789.)

Evidence in favour of the functional distinction between nouns and verbs come also from experimental studies on normal adults. For instance, it has been found that nouns are processed better and faster than verbs in comprehension tasks (Spenney & Haynes, 1989) and in lexical decision tasks (Kostic & Katz, 1987; Sereno & Jongman, 1997). Data on Hebrew have also shown that verbs and nouns show some differences in a morphological priming condition (Deutsch, Frost, & Forster, 1998; Frost, Forster, & Deutsch, 1997). Also in Italian, different stem-homograph effects were reported depending on the grammatical class of targets in visual lexical decision experiments (Laudanna, Voghera, & Gazzellini, 2002).

More importantly, returning to the topic of the ambiguity, if lexical items are also grammatically ambiguous (e.g., the noun/verb alternation, as in the word *watch* used in *I watch a tv movie on the sofa* and in *My watch says that it is 3 'o clock*), it would be confounding to assume that these words are lexically stored and processed like ambiguous words belonging to only one syntactic class.

In fact, research on the mutability of the meanings of nouns and verbs has revealed differences in sense extensibility of different grammatical categories. Ahrens (1999) and Gentner and France (1988) showed that verbs are more likely to extend their senses than nouns when a contradictory set of noun and verb are placed within one sentence. For instance, the sentence *The dog is thinking* is preferably interpreted as 'the dog is thinking like a person' rather than 'the person who looks or behaves like a dog is thinking.' This finding shows how the semantic properties of nouns and verbs are so different that when they are both inserted in a constraining sentence context, they can show different degrees of sense mutability.

The disparity between the two grammatical classes is displayed in many English homonyms, where the same word can serve as a noun or a verb, depending on context. In this subset of ambiguous words there is a crucial dichotomy: systematic vs. unsystematic homonyms. In systematic homographs, the noun/verb connection is transparent: *kiss/kiss* (coupling henceforth to be understood as "to kiss" [verb]/"the kiss" [noun]); unsystematic homographs have no connection between noun and verb forms: *squash/squash* (action and vegetable). Rubenstein, Garfield, and Millikan (1970) and Rubenstein, Lewis, and Rubenstein (1971) suggested that with systematic homographs, both nouns and verbs are stored as a unit. In contrast, Forster and Bednall (1976) and Hagoort (1989) proposed a model where the verbal and the nominal meaning of a homograph are stored separately. With respect to the frequency of occurrence, surveys by Twilley et al. (1994) and Kruez (1987) suggested that primary associations favour the noun meaning, and that noun meanings are of higher frequency than verb meanings in 75% of the cases.

To my knowledge, the majority of research which has investigated the lexical processing of ambiguous words out of context have focused on semantics and ignored the grammatical status of their experimental items, ordinarily using stimuli of various parts of speech (nouns, verbs, adjectives, etc). In many studies, some stimuli embodied meanings of various parts of speech. This may also confound the ambiguity advantage effect due to the very different semantic/syntactic attributes that different word classes possess.

Little recent research has investigated the role played by this variable, by manipulating lexical frequencies of the different meanings of category-ambiguous words and syntactic context and using a reading task. The general aim of this research line was to address the issue of whether lexical information guides interpretation independently from syntax. In an early paper investigating this topic, Frazier and Rayner (1987) examined noun-verb ambiguous words like *trains* in sentence contexts that were initially consistent with either reading (e.g., *The desert trains…*) and then were disambiguated towards one syntactic category or the other. It was observed that ambiguous words were processed faster than unambiguous controls, contrary to the predictions of the independent constraints hypothesis, which predicts slower processing.

Recently, more direct tests of whether syntactic and lexical constraints are independent have been conducted using a reading task. In some eye-tracking studies, Boland and Blodgett (2001) manipulated the syntactic context to expect either a noun (e.g., *She saw his* …), or a verb (e.g., *She saw him* …), for items that were ambiguous between noun and verb interpretations (e.g., *duck, play*), with the bias toward one of the categories varying continuously. Boland and Blodgett observed a significant correlation between lexical bias and initial fixation times in conditions where the syntactic context created an expectation for a noun, and a marginal correlation in the conditions where the syntactic context anticipated a verb. The evidence suggests that lexical information affects processing difficulty even in cases where syntactic information provides a strong cue to the correct interpretation. In another set of eye-tracking reading studies, Folk and Morris (2003) failed to find a subordinate bias effect for noun-verb ambiguous words more frequent as verbs when they were tested in noun-biasing contexts in early eye-tracking measures. More recently, a subordinate bias effect has been observed with respect to a category-ambiguous word: the word *that*, which is ambiguous between a determiner and a complementizer, is strongly biased in written text toward the complementizer reading (Gibson, 2006; Tabor, Juliano, & Tanenhaus, 1997).

A study on aphasic patients by Goldberg and Goldfarb (2005) investigated also the effects of grammatical class, using noun/verb systematic and unsystematic homographs framed in a syntactic context. They found that fluent aphasic adults tended to select verb meaning over noun meaning, whereas non-fluent aphasic adults did the opposite.

A recent event-related potentials (ERP) study on category-ambiguous words provided further evidence for the independence of lexical and syntactic constraints. In particular, Thierry et al. (2008) investigated a condition where a word was used in a syntactic context that was inconsistent with the dominant category meaning. Such conversion of one part of speech into another (what the authors call “functional shift”) is a common literary device. Thierry et al. focused on materials from Shakespeare’s writings where this device is used extensively. For example, one item from Thierry et al.'s study was *I know you don't want to speak, but lip something loving in my ear*, where the word 'lip' – most frequently used as a noun – is used as a verb, to mean whisper/speak softly. In their functional shift condition, Thierry et al. observed two components which could reflect syntactic processes: a Left Anterior Negativity (LAN) and a P600 component, a positive-going waveform peaking around 600 ms after the onset of the critical word (see e.g., Kaan, 2007, for an overview). These results suggest that speakers access the syntactic-context-inappropriate lexical meaning (e.g., the noun reading of *lip* in the example above), which leads to difficulty in integrating the word with the preceding sentence context.

Declensional class. The declensional class of nouns is another factor that has been scarcely taken into account in the literature on lexical ambiguity processing. Actually, this feature has not been an object of psycholinguistic research so far, and the existing models of speech production do not make any explicit assumptions concerning its encoding. Nevertheless, in highly inflected languages such as Italian, declension seems to play an important role during production processes because it allows the selection of the appropriate inflectional ending of the noun. But what about recognition processes? The crucial question is whether the information about declension of nouns is represented in the mental lexicon or, alternatively, it is only represented in the syntactic component of the linguistic processing system.

To my knowledge, the studies which has recently addressed the issue are essentially two. De Martino and Laudanna (2011) investigated the role of the declensional class and grammatical gender in recognizing written Italian nouns in an experimental condition where information about the surface form of the noun was kept under control. The results showed priming effects due to a modulation of grammatical gender and declensional class of the nouns: specifically, the incongruence of these grammatical and morphological features between prime and target led to higher reaction times and less accuracy. The data suggest that the lexical processing of nouns can be affected by grammatical gender and declensional class information even if processing of such information is not explicitly required (as reported in studies on gender information, such as Colè et al., (2003), De Martino et al., (2011), Paolieri et al., (2011)).

The other study which addressed the issue was carried out on Czech by using the word-picture interference paradigm[30] (Bordag & Pechmann, 2009). In Czech language, declensional class is a relevant morphological properties of nouns, whose inflectional paradigm is extremely complex. The number of declensional classes varies, depending on the criteria applied by individual grammarians (some list deviating forms as exceptions, others define a new declensional class), but usually about 14 classes are listed. In all their three experiments, the authors found congruency effects of declensional class. Specifically, picture naming times were reliably longer if the declensional classes of picture names and distractors were incongruent. Moreover, they reported that congruency effects were obtained for declensional class regardless of whether the target name and the distractor differed in form, speaking for competition at the lemma level.

In conclusion, these studies seem to show the importance of an information such as declensional class of nouns in lexical knowledge organization, which is reflected also in recognition processes of words in the written modality.

Arguments in favour of the idea that grammatical features of words (mood, tense, conjunction, etc.) are critical for lexical organization come from several empirical evidences. For example, in a set of lexical decision experiments of inflected Serbo-Croatian nouns and verbs, Kostic and Katz

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[30] About two decades ago, in an influential study conducted in Dutch, Schriefers et al. (1990) employed the so-called picture-word interference paradigm to study the production of nouns. They found that naming a picture (e.g., *dog*) takes longer when the distractor is semantically related (e.g., *cat*) than when it is unrelated (e.g., *roof*). This effect is observed when the distractor is presented shortly before or at the same time as the picture (SOA = -150/0 ms), but disappears when it is presented after the picture (SOA = + 150 ms). In contrast, when target and distractor are phonologically related (e.g., *dog/fog*) responses are faster than when they are not (e.g., *dog/roof*), provided that the distractor is presented after the target. Similar results were subsequently found in Dutch as well as in other languages (Miozzo & Caramazza, 1999; Roelofs, 1992). From then, paradigm has started to be increasingly used by experimental research on language production in order to explore lexical retrieval processes.

(1987) found that the number of inflectional alternatives affects word recognition in verbs, nouns, and adjectives. Evidence in favour of the idea that lexical access mechanisms are sensitive to grammatical properties of Italian verbs – such as inflectional class, mood, tense, and person – comes also from two experiments based on free recall of single inflected forms (Laudanna, Gazzellini, & De Martino, 2004). The results provide further support for the hypothesis that in the mental lexicon such grammatical and morphological properties are an organizational criterion for the representation of verbal forms.

The existence in Italian language of a set of ambiguous nouns with an alternation between two declensional classes gives us the opportunity to further explore this property and verify its role in the lexical access of nouns.

In summary, previous research, whether arguing for or against the ambiguity advantage, has not consistently treated the variables discussed above. In the experiments to be reported, the specific control of all of these factors hopefully provides a new perspective to re-evaluate the ambiguity effects in word recognition tasks.

First of all, I specified the ambiguity type of words, by restricting the investigation exclusively on words with two distinct, unrelated meanings (namely, homonyms)[31].

Secondly, in order to focus on meaning access modalities and on processing differences between ambiguous and unambiguous words, I carried out word recognition experiments where materials are presented out of context. I also avoided experimental tasks which directly require a recourse to semantic information (e.g., semantic categorization tasks).

Adopting the same experimental design, the same materials were tested both in lexical decision and naming tasks in order to take into account some contradictory result patterns reported in the literature on ambiguity effects between the two tasks. The idea is that a lexical decision task differs

[31] In the sixth chapter of the current dissertation, I report two lexical decision and naming experiments involving polysemous words, with two semantically related senses.

from a naming task since it involves also a decision-making process following lexical selection, as suggested by a number of researchers (e.g., Balota, 1990; Balota & Chumbley, 1984; Besner, 1983; Besner & McCann, 1987; McCann, Besner, & Davelaar, 1988; Seidenberg, Waters, Barnes, & Tanenhaus, 1984). Furthermore, I was interested in understanding the mapping between semantics and both orthographic and phonological information.

As far as the lexical decision task is concerned, all the non-words involved in the experiment were legal non-words, obtained from real Italian words by substituting only one letter, respectively situated in the middle, anterior or posterior position. In this way, it was more likely for participants to use their lexical semantic knowledge, rather than rely on superficial orthographic or morphological features, in making lexical decisions.[32]

As reported above, the meaning collecting procedure is also crucial in determining differences in ambiguity effects. In many studies, the multiple meanings of ambiguous words were collected on the basis of dictionary entries. As suggested by some researchers (e.g., Gernsbacher, 1984), gathering meanings from subjects seems to be the most relevant way of calculating the meanings, in order to examine language users' semantic knowledge.

The procedure I chose was mixed: firstly, I relied on the listing of meanings in dictionaries (all words with more than two distinct meanings were excluded from investigation); secondly, I counted the relative frequencies of multiple meanings in written Italian corpora, in order to distinguish between balanced and unbalanced homonyms[33]; finally, I carried out two off-line rating tasks (meaning generation task and semantic association task)[34], to test the actual knowledge of all multiple meanings.

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[32] Pseudohomophones (i.e., non-words that have the same pronunciations as real words, e.g., BEAF) were not used in my experiment because they are absent in languages with shallow, transparent orthographies, like Italian, with their strict correspondence grapheme-phoneme rules.

[33] All frequencies were calculated on the basis of a corpus of almost 4.000.000 occurrences (CoLFIS, Bertinetto et al., 2005).

[34] For a deep description of two off-line rating tasks adopted, see the paragraph “Method” of this chapter.

Finally, I took into consideration factors such as grammatical class, meaning frequency dominance and declensional class of ambiguous words, in order to investigate the impact of these combined variables on lexical ambiguity processing.

4.2 Grammatical class and meaning frequency dominance in recognizing Italian homonyms

4.2.1 Introduction

Many Italian words have two distinct, unrelated meanings that only casually share the same orthographic/phonological form (e.g., *eroina*, which designates both a type of drug, *heroin*, and a magnificent woman, *heroine*). When these forms – that I generally call *homonyms* – are presented within a sentence context biasing towards one of two meanings, speakers have no difficulties in interpreting their appropriate meaning by recurring to context information and encyclopedic knowledge. The question that inspired these experiments was to understand if these forms differ from unambiguous words in lexical processing, when no disambiguating material is provided. The aim of the experiments was also to verify if the recognition process of these forms is affected by two variables which have not been taken into account in most previous works on the topic:

- the grammatical status of these forms, namely, whether there are processing differences between ambiguous forms belonging to the same grammatical class (e.g., *credenza*, which means both *faith* and *cupboard*) and grammatically ambiguous forms between noun and verb (e.g., *bucato*, which means both *laundry*, nominal meaning, and *punctured,* verbal meaning).
- the meaning frequency dominance, that is whether there are processing differences between balanced ambiguous words (two meanings which have equal averaged occurrence probabilities, e.g.,

costa, meaning both *coast* and *it costs*) and unbalanced ambiguous words (having a more frequent meaning, e.g., *campione*, meaning both *champion* and *sample*).

Different ambiguity effects were expected depending on how these forms are lexically stored and processed during access to meaning.

4.2.2 Experiment 1 – Naming

4.2.2.1 Method

Stimuli. Ninety homonymous words having two unrelated meanings reported in distinct dictionary entries were selected and split in five subsets[35]:

- 18 were more frequent as nouns (N>V e.g., *abito*, dress/I live);
- 18 were more frequent as verbs (V>N e.g., *accetta*, he/she accepts/hatchet);
- 18 had two balanced nominal meanings, (N=N e.g., *credenza*, cupboard/belief);
- 18 had two unbalanced nominal meanings (N>N e.g., *campione*; champion/sample);
- 18 had two balanced nominal/verbal meanings (N=V e.g., *costa*, coast/it costs).

The threshold value for distinguishing between balanced and unbalanced forms was established on the basis of the ratio between the two frequencies. Specifically, all the homonymous words which did not exceed the ratio value of 2.5 (e.g., first meaning frequency value 10 / second meaning frequency value 4 = 2.5 ratio) were considered balanced; starting from the ratio value of three up, they were considered unbalanced.
All frequencies were calculated on the basis of a corpus of almost 4.000.000 occurrences (CoLFIS, Bertinetto et al., 2005). As to ambiguous

[35] Ambiguous forms belonged to two verbal classes (e.g., 'saliamo', meaning both 'we sit' and 'we sedate') could not be tested, because of their low frequency and size in Italian.

forms between noun and verb, the procedure to determine the two relative frequency values was simple, because the corpus is able to automatically disambiguate between distinct lemmas belonging to different grammatical classes. The same procedure was not possible for ambiguous forms belonging to the same grammatical class: in this case, a manual consultation of corpora was required in order to disambiguate the occurrence and calculate how many times an ambiguous word occurs either in a meaning or in another one.

In my study, I submitted the critical items to speakers in two off-line ratings, since it has been argued that this method provides the amount of semantic knowledge that language users are able to access on-line. The first off-line rating used to collect word meanings consisted in a meaning generation task. Eighty Italian mother-tongue undergraduates from University of Salerno participated in the meaning generation task. One hundred eighty Italian words were selected in the questionnaire: half of the words were potentially ambiguous; the other half were unambiguous words (both nouns and verbs). The items were assigned to two questionnaires of ninety words each, without a time limit. Participants were asked to say as many meanings as they could think of for each word. As I had previously excluded those ambiguous words with more than two meanings, the lists could contain either words referring only to one meanings or words referring to both meanings. The questionnaire results produced a database of word meanings that was used later to select experimental materials for the naming task. I used only the ambiguous words for which at least the 80% of subjects had listed both the meanings.

The second off-line rating was a semantic association task. The aim of this test was to specify which meanings of ambiguous words were perceived by users and their rank of frequency. As in the previous task, ninety words were potentially ambiguous words and the other half unambiguous words (both nouns and verbs). For each word, I selected the associated word which was the most reported by participants in the meaning generation task to create the word pairs (e.g. ‘scarpa’, meaning ‘shoe’, followed by ‘piede’, meaning ‘foot’). For ambiguous words, I used both the most frequent words related to the two distinct meanings (e.g., the word 'campione', meaning both 'champion' and 'sample', followed either by the word 'vittoria', meaning 'victory', and by the word 'indagine', meaning 'survey'). The two hundred seventy word pairs obtained were assigned to three questionnaires of ninety words each. Without a time limit, sixty participants were asked to rate how much the second word of each pair was semantically associated to the first word on a Likert 1-7 scale. The questionnaire results produced a database of association values that was used later to select experimental materials for the naming task. I used only the ambiguous words for which at least the value of 4 was assigned to both their meanings.

Each subset of critical stimuli was compared to a subset of unambiguous words (*baseline*), belonging to the same grammatical class of the more frequent meaning of ambiguous words. Specifically, the experimental N>V, N=N and N>N forms were matched with unambiguous nouns, while the V>N forms were matched with unambiguous verbs. Finally, the N=V forms – where there is not a dominant grammatical class - were compared both to a subset of unambiguous nouns and a subset of unambiguous verbs. From now on, I will call these forms, respectively, N=V when they were matched to noun controls and V=N when they were matched to verb controls.

Each subset of experimental items was matched to its control subset for its mean frequency (intended as the sum of relative frequencies in the case of ambiguous forms). In Table 4.1 the mean frequency values of the data set are shown.

	Frequency of ambiguous words	Frequency of noun controls	Frequency of verb controls
N>V	86.2	86.5	
V>N	83.5		82.2
N=N	33.7	33.5	
N>N	105.4	105	
N=V	22.4	22.9	
V=N	22.4		22.3

Table 4.1. Mean frequency in Experiment 1.

Experimental stimuli were also matched with control items for their mean length (in number of letters, syllables and phonemes). In Table 4.2 the mean length values of the data set are reported.

	Number of letters	Number of syllables	Number of phonemes
Exp.	5.8	2.4	5.4
Contr	5.7	2.5	5.5

Table 4.2. Mean length in Experiment 1.

The data set was also matched for orthographic neighborhood size and frequency[36]. Specifically, the values of the first parameter refer to the mean number of neighbors of my items; the values of the second

[36] The orthographic neighborhood size is the number of orthographic neighbors that a string has. An orthographic neighbor is defined as a word of the same length that differs from the original string by only one letter. For example, given the word 'cat', the words 'bat', 'fat', 'mat', 'cab', etc. are considered orthographic neighbors. The orthographic neighborhood frequency is the averaged frequency (per million) of the orthographic neighbors (definitions by Coltheart, Davelaar, Jonasson, and Besner's, 1977).

parameter refer to the number of my stimuli in each subset which have at least one more frequent neighbor. All the values[37] are shown in Table 4.3.

	Neighborhood size	Neighborhood frequency
Exp.	6.7	9.6
Contr.	6.5	7.8

Table 4.3. Mean neighborhood size and frequency in Experiment 1.

I submitted the experimental items to speakers in two off-line Likert 1-7 scale ratings, in order to match them for familiarity and imageability. Forty Italian mother-tongue undergraduates from University of Salerno participated in the two off-line tests. The mean familiarity and imageability values of the data set are reported in Table 4.4.

	Familiarity	Imageability
Exp.	4.2	4.5
Contr.	4.3	4.5

Table 1.4. Mean familiarity and imageability in Experiment 1.

In order to avoid processing differences in naming, experimental and control stimuli were matched also for their first syllable. Finally, each subset was matched for the number of double consonant words, proparoxytone words, consonant clusters and irregular phonemes (e.g. in Italian, *c, g, gn, gl*). In Table 4.5 the mean values referring to these orthographic-phonological parameters are reported.

[37] Neighborhood size and frequency values were calculated by means of an algorithm created by Claudio Mulatti and available at this website: http://dpss.psy.unipd.it/claudio/vicini.php).

	Double Consonants	**Proparoxytone words**	**Consonant clusters**	**Irregular phonemes**
Exp.	4	1	10	7
Contr	3.3	1	9.7	7.1

Table 4.5. The mean values referring to the orthographic-phonological parameters in Experiment 1.

The whole experimental list is reported in Appendix. One hundred fifty-two items were included in the list as fillers. All the filler words were real unambiguous words, matched with experimental targets for their mean length in number of letters and for their frequency. Those words, together with those in the experimental list, displayed a grammatical class distribution similar to the one of written Italian (see CoLFIS, Bertinetto et al., 2005). Specifically, fifty-seven were verbs and ninety-five were nouns.

Experimental session. The whole experiment was arranged in a single session, containing three hundred fifty items. The whole session was divided in five blocks: each block was composed of seventy items. Five randomizations for the order of presentation of the blocks and two randomizations for increasing and decreasing alphabetic order of presentation of the stimuli in each block were created.

Participants. Twenty-five participants, all students of the University of Salerno and native speakers of Italian, took part into the experiment. They served for a session lasting about forty minutes. Each participant was submitted to the whole experimental session and constituted one data point in the statistical analyses.

Equipment. Microphone and sound recorder, connected to an IBM PC running the E-Prime software (Version 1.1).

Procedure. A naming task was used as experimental paradigm (Figure 4.1). The experiment was preceded by a practice session. Participants were asked to read aloud the words presented on the screen in a fast and accurate way.
All the stimuli appeared in Courier New font, 18 point size in the centre of the computer screen. The fixation was set at 300 ms, followed by a 300 ms pause. The items remained on the computer screen for a maximum of one second. If the participants did not produce any answer within one second, the feedback 'Fuori tempo' (Out of time) appeared on the screen.

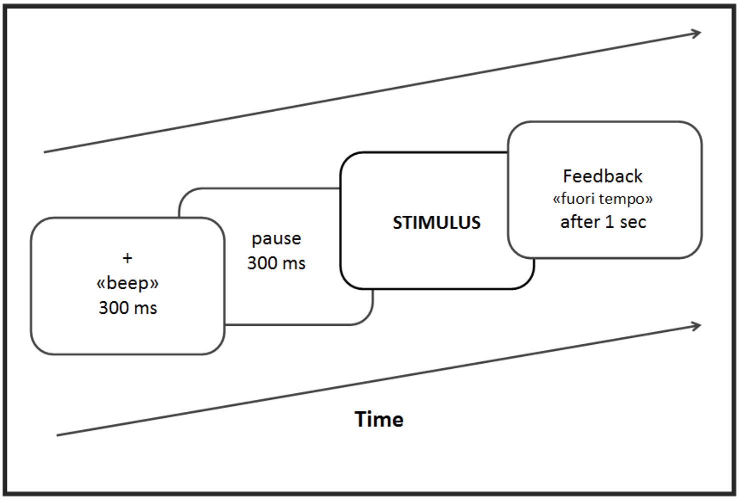

Figure 4.1. The naming procedure

The reaction times and the errors constituted the dependent variables. The reaction times were measured from the item onset to the response, and the lack of a response was scored as an error. As the microphone connected to the computer measured only reaction times, all the hesitations and reading errors were recorded and manually reported for the statistical analysis.

4.2.2.2 Results and Discussion

In Table 4.6 mean reaction times, percentage of errors and size of condition effects are shown.

	Control condition	Experimental condition	Condition effect
Reaction times	485	484	-0.1
Errors	3.2	3.1	-0.1

Table 4.6. Mean correct naming latencies (in milliseconds), percentage of errors and condition effects

The ANOVA on response latencies did not reveal any significant result (ANOVA by participants $F(1,24)=.03$; ANOVA by item $F(1,174)=.26$). Also the ANOVA on error data did not reveal any significant condition effect (ANOVA by participants $F(1,24)=.23$; ANOVA by item $F(1,174)=.12$).

In Table 4.7 mean reaction times and percentage of errors of each subset of experimental and control items are shown. Table 4.8 shows the size of condition effects in response latencies and percentage of errors.

	Control condition	Experimental condition
N>V	480 (2)	482 (1.7)
V>N	480 (2.5)	474 (4)
N=N	486 (1.5)	489 (2.5)
N>N	493 (4.7)	476 (4.2)
N=V	478 (4.3)	499 (3.4)
V=N	495 (2.8)	499 (3.4)

Table 4.7. Mean correct naming latencies (in milliseconds) and percentage of errors in each subset of stimuli

N>V	+ 2 ms (-0.3%)
V>N	- 6 ms (+1.5%)
N=N	+3 ms (+1%)
N>N	- 17 ms (-0.5%)
N=V	+ 21 ms (-0.9%)
V=N	+ 3 ms (+0.6%)

Table 4.8. Condition effects of each subset in response latencies. In parentheses the effects on errors.

Post-hoc analyses based on the ANOVA by participants on response latencies showed a significant difference between the experimental and control condition in N>N (p<.005) and in N=V (p<.01), but not in the other subsets (N>V: p<.7; V>N: p<.3; N=N: p<.4; V=N: p<.1).
In Figure 4.2 mean reaction times of each subset of experimental and control items are graphically shown; significant differences in post-hoc analyses are highlighted.

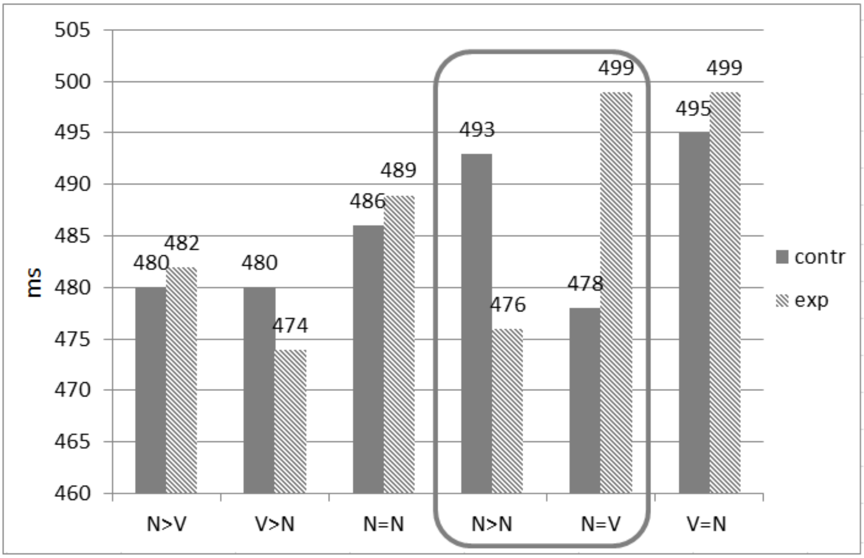

Figura 4.2. Mean reaction times in each subset of items

Post-hoc analyses based on the ANOVA by participants on error data did not reveal any significant difference between the experimental and control condition (N>V: p<.8; V>N: p<.2; N=N: p<.4; N>N: p<.7; N=V: p<.3; V=N: p<.7).
In Figure 4.3 percentages of error of each subset of experimental and control items are graphically shown.

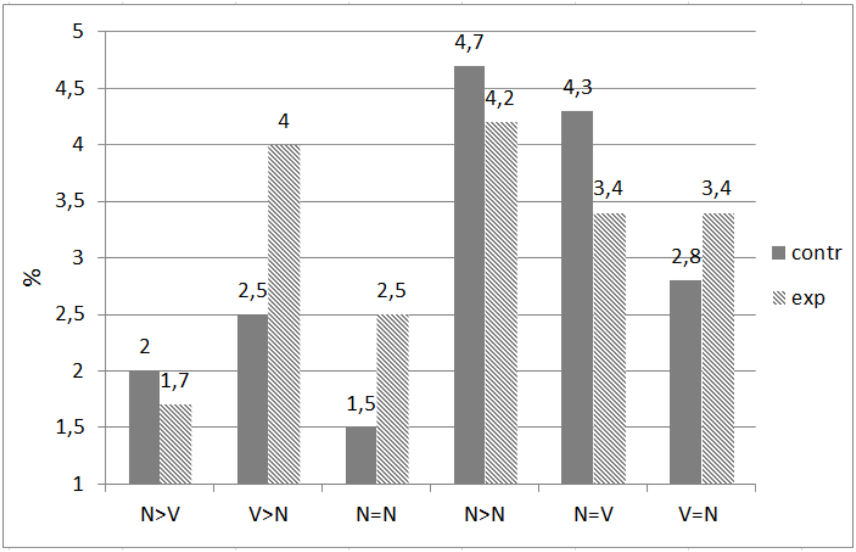

Figura 4.3. Percentage of errors in each subset of items

The overall results of the Experiment 1 do not show any processing difference between ambiguous and unambiguous words. Nevertheless, single comparisons reveal a complex pattern of results in RTs: a significant ambiguity disadvantage is found on N=V forms; a facilitation effect is reported on N>N forms; no effect is observed on the other categories.
These results seem to confirm that both grammatical category and the meaning frequency dominance play a crucial role in determining different ambiguity effects in visual word recognition.
Indeed, lexical ambiguity inhibits processing when it involves the syntactic level (different parts of speech) and when meaning frequencies are balanced. On the contrary, ambiguity facilitates processing when it occurs

only at semantic level (shared grammatical class) and when one meaning is strongly dominant. Starting from my first results, an open issue concerns what happens when we compare ambiguous and unambiguous words in a visual lexical decision task and if we can predict similar results depending on grammatical status and meaning frequency dominance.

4.2.3 Experiment 2 – Lexical decision

4.2.3.1 Method

Stimuli. The experimental and control items were the same used in Experiment 1. Five hundred two items were included in the list as fillers. One hundred fifty-two were the same real unambiguous words used in Experiment 1. The list included three hundred fifty items as pseudowords. These fillers were matched with the experimental words for length, calculated in number of letters, and they were obtained by changing one letter of existing low or medium frequency words, for 1/3 in their initial part, 1/3 in their central part and 1/3 in their final part. The whole list was composed of three hundred fifty words and three hundred fifty pseudowords.

Experimental session. The whole experiment was arranged in two different sessions, containing three hundred fifty items. In each session there were presented all fillers and half of experimental and control stimuli. The whole session was divided in five blocks: each block was composed of seventy items. Five randomizations were created for the order of presentation of the blocks and two randomizations for increasing and decreasing alphabetic order of presentation of the stimuli in each block.

Participants. Fifty-four participants, all students of the University of Salerno and native speakers of Italian, took part into the experiment. They served for a session lasting about thirty minutes. Each participant was submitted to a single experimental session. Each pair of two participants constituted one data point in the statistical analyses.

Equipment. Response box, connected to an IBM PC running the E-Prime software (Version 1.1).

Procedure. A visual lexical decision task was used (Figure 4.4). The experiment was preceded by a practice session. Participants were asked to make a decision as fast and accurate as possible. They had to press on two buttons: the button corresponding to their dominant hand for the decision 'word', the other for the decision 'non-word'. When the participants reached the 70% of correct responses in the practice session, the experiment started. All the stimuli appeared in Courier New font, 18 point size in the centre of the computer screen. The fixation was set at 300 ms, followed by a 300 ms pause. The items remained on the computer screen for a maximum of one second. If the participants did not produce any answer within one second, the feedback 'Fuori tempo' (Out of time) appeared on the screen.

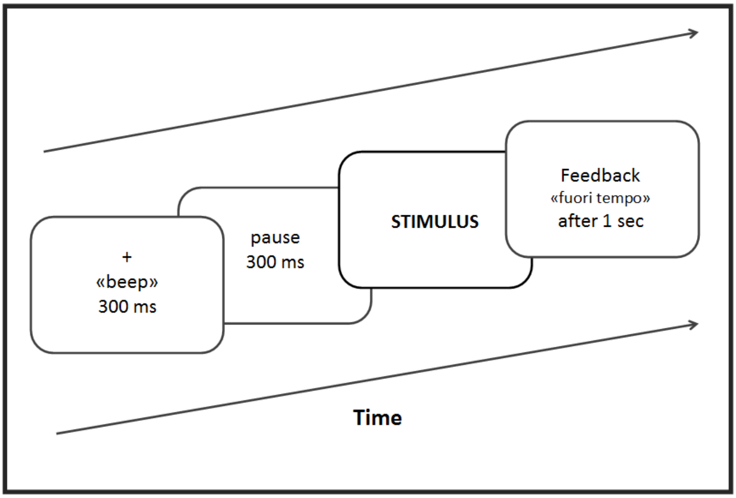

Figure 4.4. The lexical decision procedure

The reaction times and the errors constituted the dependent variables. The reaction times of right responses were measured from the item onset to the response, while the lack of a response was scored as an error, as the wrong responses.

4.2.3.2 Results and Discussion

In Table 4.9 mean reaction times, percentage of errors and size of condition effects are shown.

	Control condition	Experimental condition	Condition effect
Reaction times	523	525	+2
Errors	5.1	4.1	-1

Table 4.9. Mean correct LD latencies (in milliseconds), percentage of errors and condition effects

The ANOVA on response latencies did not reveal any significant result (ANOVA by participants $F(1,51)=.251$; ANOVA by item $F(1,182)=.18$).
The ANOVA on error data revealed a main condition effect only in the analysis by participants ($F(1,51)=7.88$, $p<.005$; ANOVA by item $F(1,182)=.01$).
In Table 4.10 mean reaction times and percentage of errors of each subset of experimental and control items are shown. Table 4.11 shows the size of condition effects in response latencies and percentage of errors.

	Control condition	Experimental condition
N>V	520 (1.3)	513 (3.6)
V>N	522 (4.5)	517 (3.3)
N=N	525 (5.65)	530 (5.6)
N>N	521 (6)	511 (3.1)
N=V	520 (5.4)	553 (4.9)
V=N	532 (8)	553 (4.9)

Table 4.10. Mean correct LD latencies (in milliseconds) and percentage of errors in each subset of stimuli

N>V	- 7 ms (+2.3%)
V>N	- 5 ms (-1.2%)
N=N	- 5 ms (-0.05%)
N>N	- 10 ms (-2.9%)
N=V	+ 33 ms (-0.5%)
V=N	+ 21 ms (-3.1%)

Table 4.2. Condition effects of each subset in response latencies. In parentheses the effects on errors.

Post-hoc analyses based on the ANOVA by participants on response latencies showed a significant difference between the experimental and control condition in N=V (p<.00) and in V=N (p<.001), but not in the other subsets (N>V: p<.2; V>N: p<.4; N=N: p<.4; N>N: p<.1).
In Figure 4.5 mean reaction times of each subset of experimental and control items are graphically shown; significant differences in post-hoc analyses are highlighted.

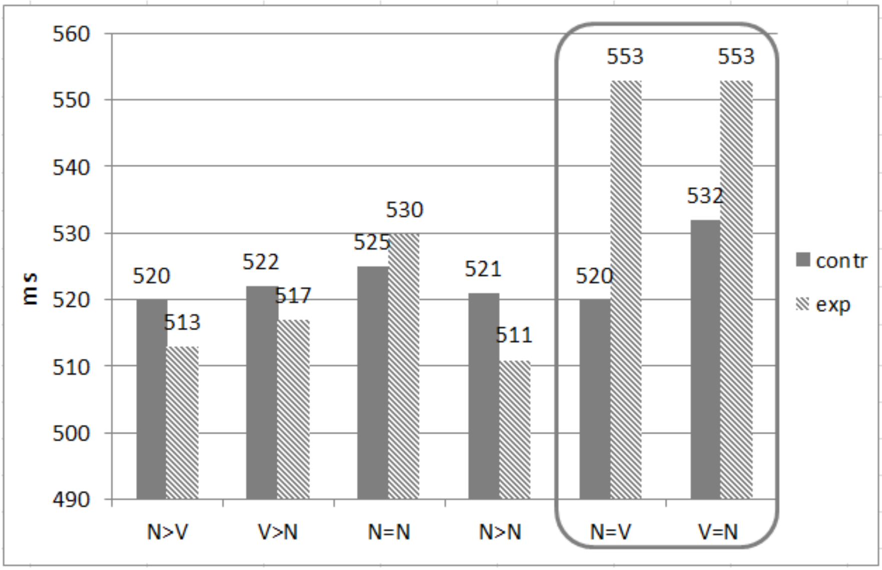

Figura 4.5. Mean reaction times in each subset of items

Post-hoc analyses based on the ANOVA by participants on error data showed a significant difference between the experimental and control condition in N>N ($p<.05$), but not in the other subsets (N>V: $p<.08$; V>N: $p<.7$; N=N: $p<.9$; N=V: $p<.4$; V=N: $p<.08$).
In Figure 4.6 percentages of errors of each subset of experimental and control items are graphically shown; significant differences in post-hoc analyses are highlighted.

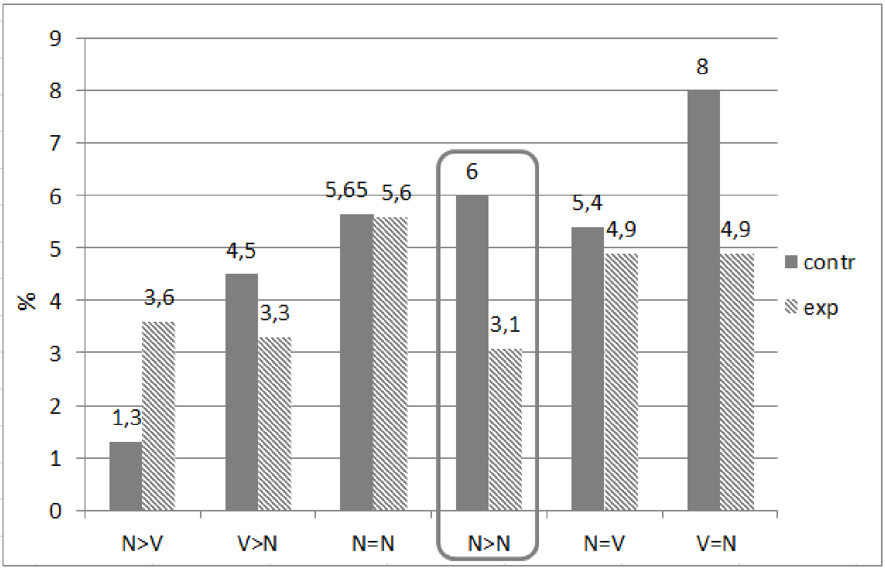

Figura 4.6. Percentage of errors in each subset of items

The overall results of the Experiment 2 do not show any processing difference between ambiguous and unambiguous words in RT analyses; alternatively, in error analyses, homonyms are recognized more accurately than unambiguous words. As in Experiment 1, single comparisons reveal different ambiguity effects: a significant ambiguity disadvantage is found on N=V forms; a facilitation effect is reported on N>N forms; no effect is observed on the other categories.
Differently from Experiment 1, the inhibitory effect reported on N=V forms is significant not only with respect to noun controls, but with respect to verb controls (V=N forms) as well. The facilitatory effect reported on N>N is significant in in error percentages, but not in RTs. The pattern of results

confirms that both grammatical category and meaning frequency dominance play a crucial role in determining different ambiguity effects in visual word recognition. As in the naming task, lexical ambiguity facilitates processing when it does not involve the syntactic level (shared grammatical class) and when one meaning is strongly dominant. On the contrary, ambiguity leads to a disadvantage when it occurs both at semantic and syntactic level and when meanings are balanced for their frequency.

4.2.4 Discussion

In the first part of my research, I started from the question of whether homonymous words differ from unambiguous words in lexical representation and processing and whether variables such as grammatical class and meaning frequency dominance affect the lexical ambiguity processing. The idea was that previous research on the topic, by arguing for or against the ambiguity advantage effect, had obtained controversy result patterns because these variables had not been consistently treated.

Relying on the results of Experiments 1 and 2, I should answer that lexical ambiguity cannot be considered as a homogeneous phenomenon, because many variables seem to play a crucial role in how multiple meanings are lexically represented and processed: looking for an ambiguity effect in visual word recognition without considering all the factors implied in the process could be misleading.

In the two experiments reported until now, I restricted my investigation to words with two unrelated meanings (homonyms) and I carried out both a naming and a lexical decision task in order to compare two visual word recognition tasks which could involve different information levels and different strategies. I also took into consideration the meaning collection procedure, which has been demonstrated to be crucial in determining the nature of the ambiguous materials. Finally, I manipulated the grammatical class and the meaning frequency dominance in order to provide a new perspective to re-evaluate the ambiguity effects in word recognition.

I found an overall absence of processing differences between ambiguous and unambiguous words. At a first glance, this result could be interpreted as a simple, uninformative null-effect, in other words as a further failed attempt to replicate the ambiguity advantage effect. Actually, the experimental design obtained by manipulating grammatical class and meaning frequency dominance allowed me to observe a more complex pattern. The null-effect obtained in the overall analyses seems to be due more to a sum of alternative effects than to a real absence of differences between conditions. Specifically, both an ambiguity advantage effect and an ambiguity disadvantage effect are found on two different subsets of ambiguous items.

When ambiguous words are frequency-balanced and belong to two different grammatical classes (N=V), the result is an inhibition in recognizing these forms. On the other hand, unbalanced forms with two nominal meanings (N>N) are recognized faster and more accurately than unambiguous words. The other experimental subsets do not exhibit ambiguity effects. From a point of view, they could be situated in the middle of a continuum: N=N forms are similar to N>N in terms of grammatical class but differ from them as the two meanings are frequency-equal; on the other hand, N>V and V>N resemble to N=V since they have an alternation between noun and verb, but differently from N=V one meaning is always much more frequent than the other one.

Starting from the results of my first two experiments, an open issue concerns how grammatical class and meaning frequency dominance effects could be explained and at which stage of lexical processing they are situated. The idea is that the processing differences I found could reflect different lexical representations among categories of ambiguous items. We can imagine that visual word recognition process requires multiple stages in which different information levels are processed. Firstly, when speakers are presented with the printed words, they activate the orthographic information which is necessary to process the visual input. At this early stage, ambiguous words are not different from unambiguous words: in Italian most ambiguous words are also homographs, which means that they share the written form[38]. The following step is the activation of morpho-syntactic information about words, such as the word class information. At this stage, we can situate the ambiguity disadvantage effect depending on the grammatical class: for syntactically ambiguous forms, we can predict two distinct representations, corresponding, respectively, to the nominal and the verbal functions. The same representation pattern is not be supposed for ambiguous forms belonging to the same grammatical class, which share the representation at this level. Multiple morpho-syntactic representations are expected to compete with each other as they transmit different information. The competition process is supposed to be stronger when two alternative meanings are frequency-equal (N=V). A slightly different interpretation of the competition process is that when words are syntactically ambiguous, a decision-making process between alternative meanings could be necessary.

At this point of the lexical process, semantic information has to be activated. Differently from unambiguous words, all the ambiguous items at this level are supposed to have two distinct representations, each corresponding to the specific meaning they can assume. Even at this level, the activation of the single semantic representations is mediated by the relative frequency of each occurrence. As to unbalanced homonyms, we may suppose that the representation corresponding to the most frequent meaning will reach the activation threshold needed to recognize the word before the other one. Nevertheless, we cannot exclude that in some cases even the subordinate meaning will reach the activation threshold before the word is recognized (for example, because of idiosyncratic differences among items or speakers). It follows an ambiguity advantage effect on N>N forms as a result of the sum of activations. The same advantage is not found on N=N forms: here we can imagine a competition process between distinct semantic representations which are frequency-equal. Finally, on N>V and V>N forms no effect is found: even though these forms are syntactically ambiguous, the competition process between distinct

[38] All the ambiguous items I tested in my experiments were both homographs and homophones.

morpho-syntactic representations is easily won by the most dominant representation. As to visual lexical decision task, we can suppose that the processing will end at this stage; in the case of naming task it is necessary to re-activate the morpho-syntactic representations where phonological information is stored. A graphical representation of lexical access of homonyms is displayed in Figure 4.7.

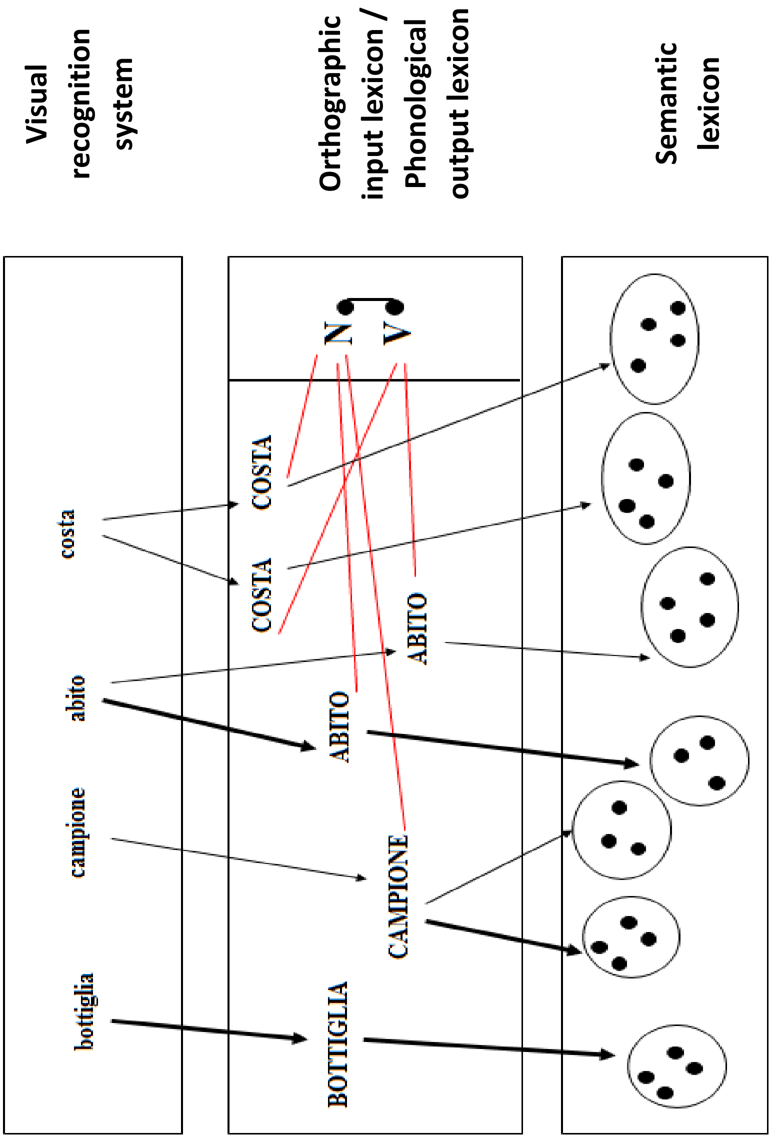

Figure 4.7. Lexical processing of homonyms

The results obtained in my first experiments shed light not only on lexical ambiguity effects but also on information levels which are implied in the lexical access. The idea is that it would be necessary to activate abstract information such as grammatical class even though it is not strictly required to execute the task. According to this hypothesis, the results of these experiments can be easily accommodated within the framework of models of language production. As predicted by language production models, the level of grammatical category information can be posited at the *lemma* level in Levelt's terms (1989) or at the level of syntactic properties processing according to Caramazza (1997). Grammatical class is one of those word categories that must be specified in order to access and retrieve the word-form and in order to provide information about the way in which the word be assembled with other linguistic elements of the sentence. Thus, if it is relatively clear that grammatical category is relevant during sentence computation but also in single word production, we have fewer elements at our disposal to decide whether information of this kind is also represented in the input lexicon and if it is necessary to correctly access and recognize visual words.

The grammatical class effects reported in my two experiments provide a little evidence in favour of the idea that even in visual word recognition process it would be necessary to access such abstract information pertinent to words.

The following step of my work was to investigate how the relation between grammatical class and meaning frequency dominance is perceived by speakers. In other words, since I have found different ambiguity effects depending on these variables, I wanted to control the frequency distributions of syntactically ambiguous words. The most direct way to address the question was to carry out an online grammatical decision task, where participants were asked to assign the grammatical class to the presented words as soon as possible. In this way, subjects were explicitely asked to access grammatical class information and verify how it interacts with meaning frequency dominance of homonyms.

4.3 Experiment 3
An online grammatical decision task: investigating grammatical ambiguity effects

4.3.1 Introduction

As reported in previous experiments, grammatical class seems to be relevant in determining different ambiguity effects: the syntactic ambiguity of a word (noun vs. verb) inhibits the lexical processing when homonyms are balanced for frequency (N=V forms). The finding cannot be exclusively attributed to the meaning frequency dominance, since the same inhibitory effect is not found for N=N forms, which maintain the nature of balanced homonyms but are not syntactically ambiguous. The aim of Experiment 3 was to investigate how grammatical class and meaning frequency dominance correlate in the perception of speakers. Starting from frequency values (reported in CoLFIS) of grammatically ambiguous words, an online grammatical decision task was carried out. While for unbalanced forms I expected an overlap between objective frequency values and responses by participants, for balanced words the prediction was to observe a bias towards nominal assignments "by default", in absence of context information and frequency dominance effects. This hypothesis is based on some data obtained by Postiglione and Laudanna (submitted), where the processing of Italian polysemous past participles, which were either more frequent as nouns (*impiegato* clerk/employed) or as verbs (*condannato* condemned/convict), was investigated. Differently from homonymous words I adopted, which had two unrelated meanings, these forms are only grammatically ambiguous. In an online grammatical decision task on these forms, a strong bias to nominal assignment was found, even though the forms were more frequent as verbs. The result was interpreted as an evidence of the idea that when words are presented in isolation, they are lexically accessed as nouns "by default". The meaning frequency effect seems to play a weaker role on these forms, presumably because all representations overlap and share a unique core meaning. It results that they are all activated in lexical processing, independently by their frequency distributions.

4.3.2 Method

Stimuli. Sixty homonymous words were selected from the same database used for Experiments 1 and 2 and split in three subsets:

- 20 were more frequent as nouns (N>V e.g., *abito*, dress/I live);
- 20 were more frequent as verbs (V>N e.g., *accetta*, he/she accepts/hatchet);
- 20 had two balanced nominal/verbal meanings (N=V e.g., *costa*, coast/it costs).

The whole experimental list is reported in Appendix. Four hundred and forty-four unambiguous real words were included in the list as fillers. Half of them were nouns and the other half were verbs. The whole list was composed of five hundred-four words.

Experimental session. The whole experiment was arranged in a single session, containing all the items. The whole session was divided in seven blocks: each block was composed of seventy-two items. Seven randomizations were created for the order of presentation of the blocks and two randomizations for increasing and decreasing alphabetic order of presentation of the stimuli in each block.

Participants. Forty-three participants, all students of the University of Salerno and native speakers of Italian, took part into the experiment. They served for a session lasting about thirty minutes. Each participant was submitted to the whole experimental session.

Equipment. The same as in Experiment 2.

Procedure. I adopted the same experimental paradigm used by Postiglione and Laudanna, which is called 'grammatical decision'. (Figure 4.8):

participants were asked to assign the grammatical class to the words as fast and accurate as possible. Specifically, they had to press on one button of the response box for the decision 'noun' and on the other for the decision 'verb'[39]. When the participants reached the 70% of correct responses in the practice session, the experiment started. All the stimuli appeared in Courier New font, 18 point size in the centre of the computer screen. The fixation was set at 300 ms, followed by a 300 ms pause. The items remained on the computer screen for a maximum of one second. If the participants did not produce any answer within one second, the feedback 'Fuori tempo' (Out of time) appeared on the screen.

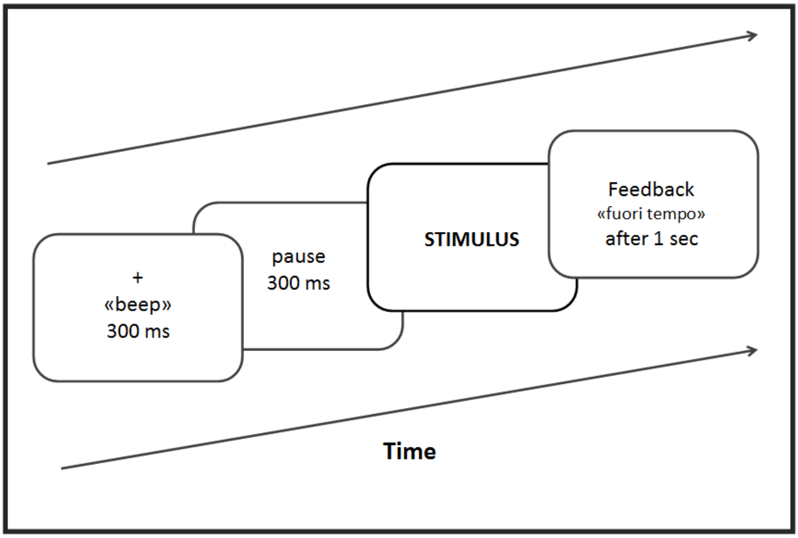

Figure 4.8. The grammatical decision procedure

I measured the percentage of noun and verb responses, for each experimental subset, and response latencies.

[39] In order to avoid hand-dominance effects biasing towards either noun or verb assignments, I created two groups of subjects: half of them had to press on the right button for the decision 'noun' and on the left button for the decision 'verb'; the other half of participants received the opposite instructions.

4.3.3 Results and Discussion

In Table 4.13 mean reaction times, percentage of responses and size of condition effects are shown.

	Noun decision	Verb decision	Condition effect
Reaction times	570	570	0
Percentages	53	47	-6

Table 4.13. Mean GD latencies (in milliseconds), percentage of responses and condition effects

The ANOVA on reaction times did not reveal any significant results (ANOVA by participants $F(1,41)=.13$; ANOVA by item $F(1,111)=.01$). Also, the ANOVA on response percentages did not reveal any significant results (ANOVA by participants $F(1,41)=2.92$; ANOVA by item $F(1,112)=1.39$).
In Table 4.14 the mean reaction times and percentage of errors of each subset of experimental and control items are shown. Table 4.15 shows the size of condition effects in response latencies and percentage of errors.

	Noun decision	Verb decision
N>V	575 (67)	592 (33)
V>N	563 (31)	552 (69)
N=V	572 (60)	566 (40)

Table 4.14. Mean latencies (in milliseconds) and percentage of responses in each subset of stimuli

N>V	+ 17 ms (-34%)
V>N	- 11 ms (+38%)
N=V	- 6 ms (-20%)

Table 4.15. Grammatical assignment of each subset in response latencies. In parentheses the effect on responses.

Post-hoc analyses based on the ANOVA by participants on response latencies showed a significant difference between noun and verb decisions in N>V forms ($p<.01$) and in V>N forms ($p<.001$), but not in N=V forms ($p<.2$).

In Figure 4.9 mean reaction times of each subset of experimental and control items are graphically shown; significant differences in post-hoc analyses are highlighted.

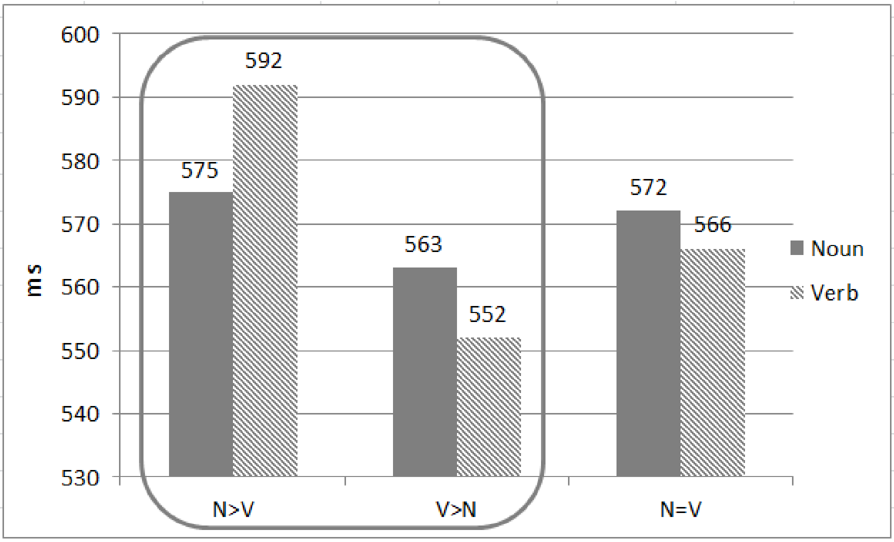

Figura 4.9. Mean reaction times in each subset of items

Post-hoc analyses based on the ANOVA by participants on response percentages showed a significant difference between experimental and control condition in all subsets: N>V ($p<.001$), V>N ($p<.001$), N=V ($p<.001$).

In Figure 4.10 percentage of responses of each subset of experimental and control items are graphically shown; significant differences in post-hoc analyses are highlighted.

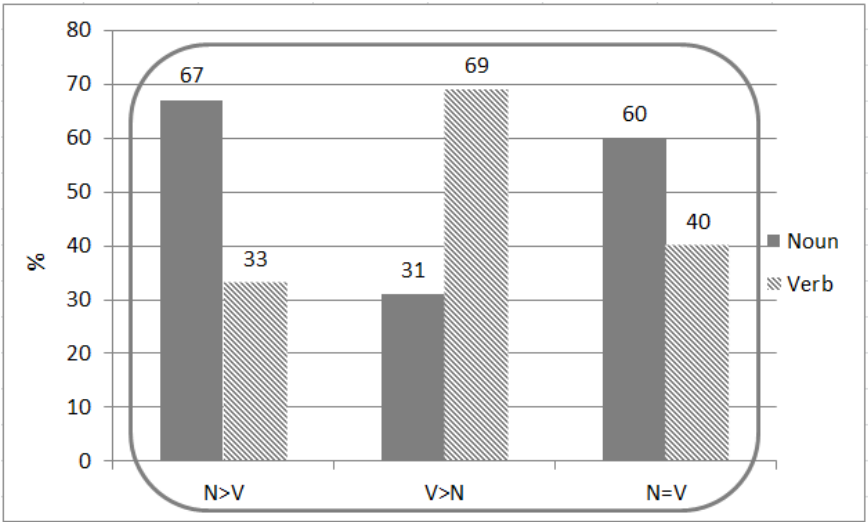

Figura 4.10. Percentage of responses in each subset of items

The overall results do not show significant differences in assignment of grammatical class to the ambiguous words. Nevertheless, single comparisons reveal a more complex pattern depending on the meaning frequency dominance of homonyms: an overlap between objective frequency values and subjective responses is reported for unbalanced forms; namely, N>V forms are recognized significantly faster and more often as nouns, while V>N forms show the opposite pattern. Finally, as expected, I report a bias to nominal assignments for balanced words (N=V), which conforms to the "nominal dominance" hypothesis, in absence of meaning dominance effects and contextual information. Differently from polysemous past participles used in Postiglione and Laudanna (submitted), where the nominal assignment was preferred more often, here the meaning frequency plays a more crucial role in determining the lexical access of homonyms. Indeed, when forms are unbalanced, the dominant meaning always prevails on the other one, presumably because it is the only one which is activated (or more activated, if one prefers a more "exhaustive" view of the lexical access). However, the most important difference between my stimuli and polysemous verbs adopted by Postiglione and Laudanna is that in the first case ambiguous forms have two unrelated meanings, corresponding to distinct lexical representations, while in the second case items share a common core meaning, presumably corresponding to a unique lexical representation.

This result pattern is compatible with the findings reported by many authors (see Paragraphs 3.6-3.8) which support the idea of a distinction between homonymy and polysemy based on differences in the way these forms are lexically represented and accessed.

4.4 Experiment 4
Declensional class and meaning frequency dominance in recognizing Italian homonyms

4.4.1 Introduction

The aim of this experiment was to investigate the lexical processing of Italian nouns which are ambiguous for their declensional classes (e.g., '*arti*', meaning both '*arts*' and '*limbs*').

The prediction was to report a similar ambiguity inhibitory effect found for balanced homonyms belonging to different grammatical classes in Experiments 1 and 2, on the basis of the idea that declensional class information is accessed during lexical processing. For these types of nouns I supposed the existence of two distinct representations at the orthographic input level, with distinct morpho-syntactic information, like N=V forms. The prediction at the basis of this experiment came from a more general assumption about which information levels are involved in word lexical access.

It is reasonable that information about declensional class of nouns is an organizational criterion for nominal paradigms in the lexicon. The main characteristic of this feature is that it provides useful information to access and retrieve the word-form and to combine the noun with other linguistic elements of the sentence. However, the available evidence does not allow us to draw any conclusion about the way declensional class of nouns gets involved during lexical processing: comprehension models did not approach the problem. Hence, I became interested in exploring whether this information may affect the performances of participants in a comprehension task, namely whether it is also represented in the input lexicon.

In Italian the existence of a restrict set of nouns that are ambiguous for their declensional class gave me the experimental possibility to address the question and explore whether the visual recognition of these forms differs from unambiguous nouns. Since declensional class is a morpho-syntactic property, I hypothesized that the effect can be detected in word recognition, as for other syntactic feature of nouns, like gender (De Martino, Bracco & Laudanna, 2011; De Martino & Laudanna, 2012), or for morphological information (Burani & Laudanna, 1992; Feldman, 2000; Laudanna et al., 1989; 1992; Rastle, Davis, Marslen-Wilson, & Tyler, 2000), or even for purely syntactic factors (Goodman, McClelland, & Gibbs, 1981; Pickering & Branigan, 1998; Seidenberg, Waters, Sanders, & Langer, 1984).

In order to focus on the role played by declensional class, I carried out a lexical decision task on homonymous nouns belonging to two different declensional classes and compared them with unambiguous nouns[40]. I manipulated the meaning frequency dominance (balanced vs. unbalanced homonyms) of ambiguous materials.

4.4.2 Method

Stimuli. Twenty homonymous nouns with two unrelated meanings of different declensional classes[41] were selected. The experimental items

[40] I did not compare in this experiment these forms with ambiguous nouns belonged to the same declensional class (e.g., ‘credenza’, N=N or ‘campione’, N>N), because I had already tested them in a lexical decision task (Exp. 2).

[41] Because of the limited number of this kind of nouns in Italian, I could not exclude from my investigation forms which were ambiguous not only among declensional classes but also for gender and/or number information. Nevertheless, declensional class ambiguity

were split in two subsets on the basis of the meaning frequency dominance:

- 10 had two balanced nominal meanings, (N=N e.g., *teste*, heads/witness);
- 10 had two unbalanced nominal meanings (N>N e.g., *arti*; arts/limbs).

The threshold value to distinguish between balanced and unbalanced forms was the same established for the Experiment 1-3. All frequencies were calculated on the basis of a corpus of almost 4.000.000 occurrences (CoLFIS, Bertinetto et al., 2005). I submitted the critical items to speakers in the same off-line rating task adopted for the previous experiments, in order to verify the subjective knowledge of both meanings of the words. Each subset of critical stimuli was matched with a subset of unambiguous nouns ending in *–e*[42] (*baseline*), for their mean frequency (intended as sum of relative frequencies in the case of ambiguous forms). In Table 4.16 the mean frequency values of the data set are shown.

	Frequency of ambiguous words	**Frequency of control words**
N=N	72	71
N>N	125	125.5

Table 4.16. Mean frequency in Experiment 4.

Experimental stimuli were also matched to control items for their mean length (in number of letters, syllables and phonemes).

In Table 4.17 the mean length values of the data set are reported.

was the only variable which characterized all the stimuli, while gender and number ambiguities were related to few subsets of items.

[42] Italian nouns ending with –e can be either masculine or feminine: the only way to know their gender is by consulting a dictionary or deducting it from the article in front of the noun. In all the other cases, the vowel ending allows speakers to predict the noun gender (-a for feminine gender and –o for masculine gender), apart from some exceptions (e.g., the feminine word *mano*, meaning ‘hand’).

	Number of letters	Number of syllables	Number of phonemes
Exp.	4.7	2.1	4.5
Contr.	4.6	2.1	4.6

Table 4.17. Mean length in Experiment 4.

In order to match experimental and control stimuli for gender and number information, control words were either masculine or feminine and either singular or plural number nouns. Two off-line Likert 1-7 scale ratings were submitted to a group of participants, in order to match them for familiarity and imageability. Forty Italian mother-tongue undergraduates from University of Salerno participated in the two off-line tests. The mean familiarity and imageability values of the data set are reported in Table 4.18.

	Familiarity	Imageability
Exp.	4.8	4.3
Contr.	4.6	4.5

Table 4.18. Mean familiarity and imageability in Experiment 4.

The whole experimental list is reported in Appendix. One hundred eighty items were included in the list as fillers. Eighty items were real unambiguous nouns, matched with experimental targets for their mean length in number of letters and for their frequency. The list included one hundred items as pseudowords. These fillers were matched with the experimental words for length, calculated in number of letters, and they were obtained by changing one letter of existing low or medium frequency words, for 1/3 in their initial part, 1/3 in their central part and 1/3 in their final part. The whole list was composed of one hundred words and one hundred pseudowords.

Experimental session. The whole experiment was arranged in a single session, containing two hundred items. The whole session was divided in four blocks: each block was composed of fifty items. Four randomizations were created for the order of presentation of the blocks and two randomizations for increasing and decreasing alphabetic order of presentation of the stimuli in each block.

Participants. Seventy-four participants, all students of the University of Salerno and native speakers of Italian, took part into the experiment. They served for a session lasting about thirty minutes. Each participant was submitted to the whole experimental session and constituted one data point in the statistical analyses.

Equipment and *procedure* were the same as in Experiment 2.

4.4.3 Results and Discussion

In Table 4.19 mean reaction times, percentage of errors and size of condition effects are shown.

	Control condition	Experimental condition	Condition effect
Reaction times	530	540	+10
Errors	3.7	5.3	+1.6

Table 4.19. Mean correct LD latencies (in milliseconds) and percentage of errors in each condition.

The ANOVA on response latencies showed a main effect of condition in the analysis by participants ($F(1,73)=13.04$; $p<.001$; ANOVA by item $F(1,36)=.51$). Also the ANOVA on error data revealed a main effect of condition in the analysis by participants ($F(1,73)=4.21$; $p<.05$; ANOVA by item $F(1,36)=.60$).
In Table 4.20 mean reaction times and percentage of errors for each subset of experimental and control items are shown. Table 4.21 shows the size of condition effects in response latencies and percentage of errors.

	Control condition	Experimental condition
N>N	534 (3.8)	530 (3.4)
N=N	526 (3.6)	550ms (7.2)

Table 4.20. Mean correct LD latencies and percentage of errors in each subset of stimuli

N>N	- 4 ms (-0.4%)
N=N	+ 24 ms (+3.6%)

Table 4.21. Condition effects of each subset in response latencies. In parentheses the effects on errors.

Post-hoc analyses on response latencies based on the ANOVA by participants showed a significant difference between experimental and control condition in N=N ($p<.001$), but not in the other subset (N>N: $p<.6$).
In Figure 4.11 mean reaction times of each subset of experimental and control items are graphically shown; significant differences in post-hoc analyses are highlighted.

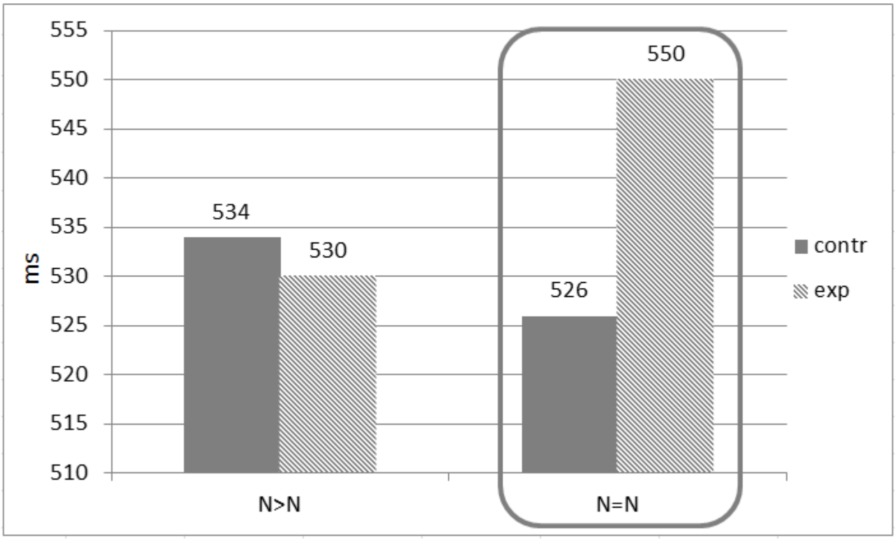

Figura 4.11. Mean reaction times of each subset of items

Post-hoc analyses on error data based on the ANOVA by participants showed a significant difference between the experimental and control condition in N=N (p<.001), but not in the other subset (N>N: p<.7).

In Figure 4.12 percentages of errors of each subset of experimental and control items are graphically shown; significant differences in post-hoc analyses are highlighted.

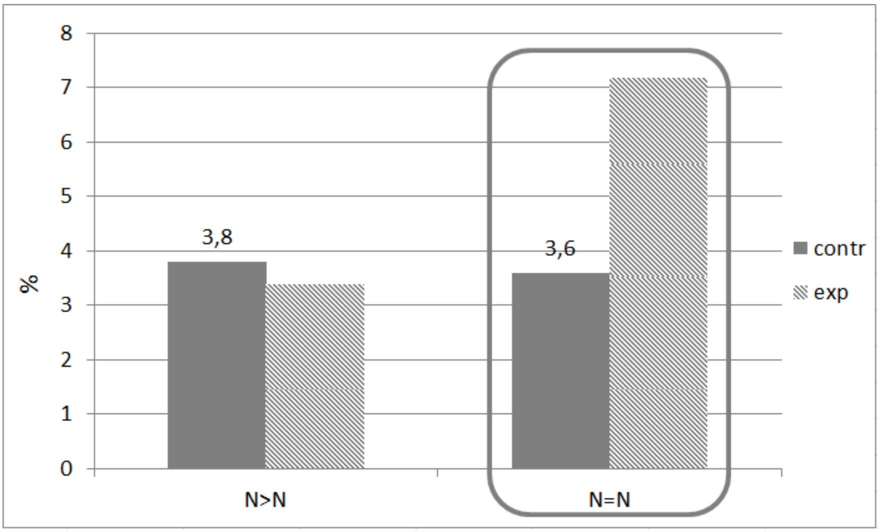

Figura 4.12. Percentage of errors of each subset of items

The overall results reveal that ambiguous nouns are recognized slower and worse than unambiguous nouns. The ambiguity disadvantage effect can be attributed not only to the semantic ambiguity of these forms, but also to the fact that they belong to two distinct declensional classes. Thus, the same ambiguity disadvantage was not found in Experiments 1 and 2, where semantically ambiguous nouns belonging to the same declensional class (e.g., *credenza*) did not differ in processing from unambiguous nouns.

The single comparisons reveal a further processing difference: the ambiguity disadvantage is found only on N=N forms, both in speed and accuracy of lexical decisions. The idea is compatible with my initial hypothesis: ambiguous nouns with an alternation between declensional classes would have two distinct representations in the input orthographic lexicon and compete with each other during lexical access. The competition process is stronger for balanced ambiguous nouns. A similar result pattern was found in Experiment 1 and 2, where balanced homonyms with an alternation between noun and verb (N=V) showed an inhibitory effect, which was not found for unbalanced grammatically ambiguous forms (N>V and V>N).

As for homonyms tested in Experiment 1 and 2 (see Paragraph 4.1.4), a graphical representation of lexical access of homonymous nouns is displayed in Figure 4.13.

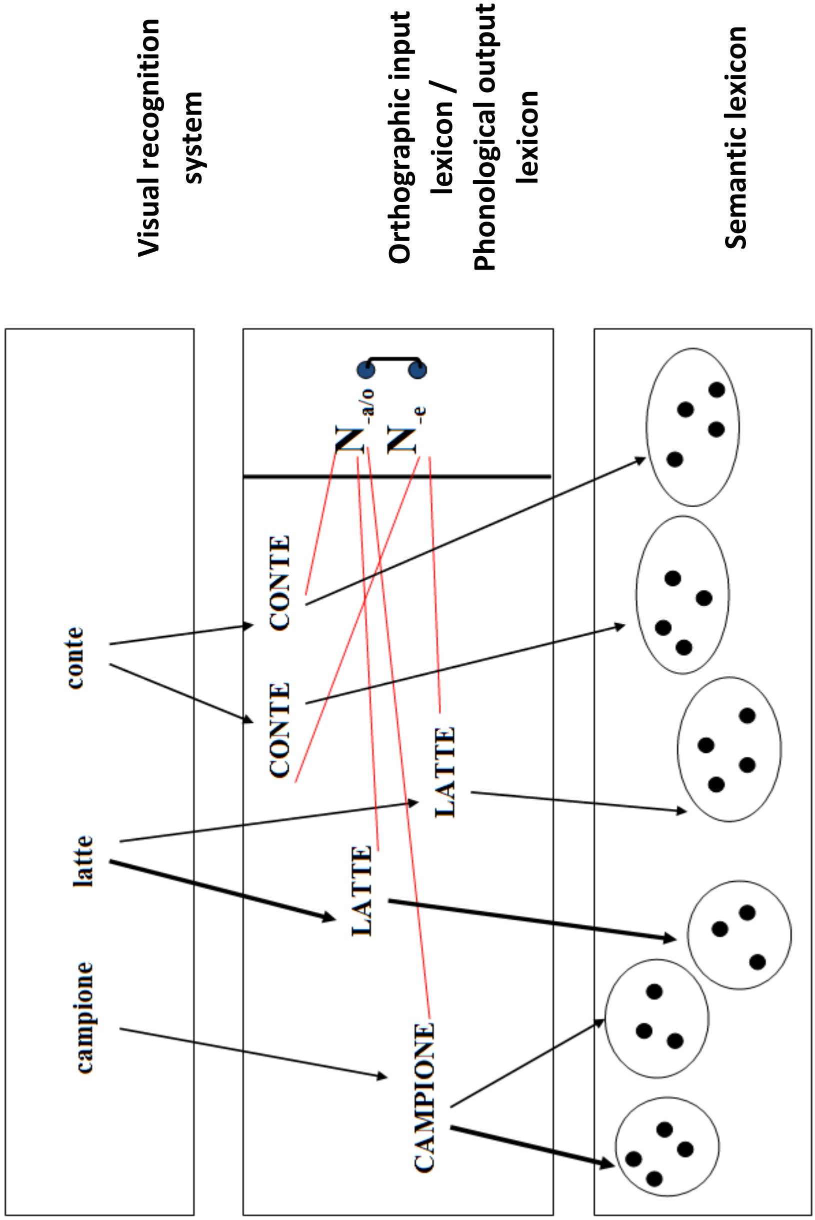

Figure 4.13. Lexical processing of homonymous

These results are compatible with a more general prediction about the role played by declensional class information in word recognition. Like other types of abstract information (e.g., noun gender, grammatical class, morphological and syntactic features), declensional class would be stored as a property of nouns at a representational level and accessed during lexical processing, even though its activation is not explicitly requested by the task.

4.5 General discussion

In the first part of my research, the hypothesis of processing differences between ambiguous and unambiguous words in visual word recognition was evaluated. Even though a great deal of research addressed the question, the so called “ambiguity advantage effect” – which predicts that bare lexically ambiguous words are recognized faster and better than unambiguous words – has not been universally confirmed. One possible reason (see Chapter 3 for a review) is that lexically ambiguity has been erroneously treated as an homogeneous phenomenon. Actually, many variables seem to affect the lexical processing of ambiguous words, such as grammatical class, meaning collection procedure, experimental paradigm, number and relatedness of meanings. In the first part of this study, I tried to re-evaluate lexical ambiguity effects in single word recognition tasks by taking into account the impact of several semantic, grammatical, distributional and morphological variables.

In all the experiments, the investigation was restricted to ambiguous words with two distinct, unrelated meanings (homonyms). I carefully adopted a mixed meaning collection procedure, which has been demonstrated to be crucial in determining ambiguity effects. The experimental material was selected on the basis of both dictionary entries and off-line ratings aimed at testing the actual knowledge of multiple meanings by speakers. I excluded from my investigation ambiguous forms with more than two meanings, in order to avoid potential effects of number of meanings. Finally, I chose to investigate the lexical processing in bare words because I was interested in focusing on the meaning access modalities and on processing differences between ambiguous and unambiguous words, without any biasing contextual information.

In the first two experiments, I manipulated the meaning frequency dominance and the grammatical class of homonyms and obtained subsets of experimental materials, tested in naming and in lexical decision. The results are similar in both experiments: no overall differences are found between ambiguous and unambiguous words. However, single comparisons reveal a more complex pattern: lexical ambiguity inhibits processing when it involves the syntactic level (different parts of speech) and when meaning frequencies are balanced. On the contrary, ambiguity facilitates processing when it occurs only at semantic level (shared grammatical class) and when one meaning is strongly dominant.

At this point, the aim of the Experiment 3 was to investigate how meaning dominance and grammatical class interact with the perception of speakers. Starting from frequency values of grammatically ambiguous words, I carried out an online grammatical decision task on grammatically ambiguous words. While for unbalanced forms (N>V and V>N) an overlap between objective frequency values and responses was reported, for balanced words a bias to nominal assignments was found, in absence of context information and frequency dominance effects.

Differently from polysemous past participles used by Postiglione and Laudanna (submitted), where the nominal assignments were always preferred, my results seem to confirm that meaning frequency dominance affects the lexical access of homonyms. More generally, the findings are compatible with the idea that the homonymy/polysemy distinction is not only linguistically grounded, but reflects differences in the way these forms are lexically represented and accessed.

In Experiment 4 I tested a different subset of experimental material, composed of homonymous nouns belonging to two different declensional classes and with different meaning frequency dominance.

A significant ambiguity disadvantage on ambiguous nouns with two frequency-equal meanings was observed. Since the same pattern was not found in Experiment 1 and 2 on semantically ambiguous nouns belonging to the same declensional class, here the inhibiiton can be attributed to the ambiguity between declensional classes.

Generally speaking, the results of the first four experiments can be interpreted as an evidence that the processing differences reflect different lexical representations among categories of ambiguous items.

As to semantic information level, all the ambiguous items I tested are supposed to have distinct representations, each one corresponding to the specific meaning they can assume. At the visual recognition level, it is supposed that all ambiguous forms are represented in the same way: namely, they share the orthographic form since they are homographs.

Thus, the processing differences found are ascribed to different representation modalities at the orthographic input/phonological output lexicon level. Specifically, ambiguous words with an alternation either between two grammatical classes (noun and verb) or between two declensional classes (-e nouns and –a/-o nouns) would have two distinct representations at this level and compete with each other during lexical access. Since the lexical access is mediated by the relative frequencies of ambiguous words, the competition process will be stronger in the case of balanced ambiguous forms. This is not the case of ambiguous words belonging either to the same grammatical class or to the same declensional class. An ambiguity advantage effect is found only in ambiguous words which do not encode the predicted competition source. Specifically, ambiguous words of the same grammatical class (noun) and the same declensional class, which are also frequency-unbalanced, are accessed faster and better in visual word recognition tasks. Even though it is reasonable to expect for these forms that the most frequent meaning is activated before than the other one, I cannot exclude that in some cases even the subordinate meaning will reach the activation threshold before the competing representation. Thus, the summed activation facilitates the word recognition.

The results obtained in the first experiments shed light not only on lexical ambiguity effects but also on a more general assumption about which information levels are involved in word lexical access.

The processing differences depending on both the grammatical class and the declensional class reported in my experiments provide a little evidence in favour of the idea that such abstract level information would be represented in the input lexicon and necessary accessed even though they are not explicitly required by the task.

In conclusion, these findings seem to show how it is crucial to assume a new perspective in order to investigate the ambiguity effects in word recognition. Only by taking a broader view of the possible factors which affect the lexical processing of ambiguous forms we will be able to direct our efforts more productively in order to understand the lexical ambiguity processing and its relation to other aspects of language comprehension.

My study does not pretend to be exhaustive in the attempt to account for literature discrepancies on the topic: other variables which were not considered in my experiments could play a role in lexical ambiguity processing. The challenge of explaining how ambiguous words are lexically accessed by speakers is one that researchers continue to face, since many questions have yet to be answered.

As a further refinement of my hypothesis, the next step of my research is to investigate the lexical processing of ambiguous words when one meaning is biased by “contextual” information. Although it is not a matter of recent debate that context affects access procedures, the question which inspires my next experiments is to investigate at which stage of lexical access the context operates and how it interacts with grammatical class and meaning frequency dominance information.

4.6 CONCLUDING REMARKS

In this chapter I aimed at re-examining the effect of lexical ambiguity on word recognition, by considering some factors that were not fully analyzed in previous research on the topic. Specifically, I investigated the processing of ambiguous word with two unrelated meaning, namely homonyms in four visual word recognition experiments.

Summing up:

- The overall results do not show any processing difference between homonymous words and unambiguous words in visual word recognition tasks.
- Nevertheless, single comparisons among subsets of ambiguous words reveal a more complex pattern of results. Specifically, lexical ambiguity inhibits processing when it involves either the syntactic level (different parts of speech) or the morphological level (different declensional classes) and when meaning frequencies are balanced. On the contrary, ambiguity facilitates processing when it occurs only at semantic level (shared grammatical and declensional classes) and when one meaning is strongly dominant.
- The processing differences seem to reflect different lexical representations among categories of ambiguous items. My findings confirm that considering lexical ambiguity as a unique, homogeneous phenomenon could be confusing, as actually many variables seem to play a crucial role in determining different results.
- The results obtained in my first experiments shed light not only on lexical ambiguity effects but also on a more general assumption about which information levels are involved in word lexical access.

Open issues:

- Which role is played by semantic and morphological information in lexical ambiguity processing?

- How does contextual information interact with grammatical class and meaning frequency dominance?
- Does lexical processing of polysemous words differ from homonymous words?
- Which role is played by grammatical class and frequency dominance in lexical access of polysemous words?


THE THESIS
WHAT IS THE STATISTICAL SIGNIFICANCE OF YOUR RESULTS??
IT'S IN THE APPENDIX!
RUN MORE EXPERIMENTS!
I ALREADY DID!
phd.stanford.edu/comics
WOW! I'VE NEVER SEEN ANYONE MOVE THAT FAST!
HE IS THE ONE. THE FIRST TO FINISH IN 3 YEARS...
I...ZZZ...AM...THE.. ONE..ZZZZ...
SOMEONE WAKE HIM BEFORE HE DROOLS ON THE COMPUTERS AGAIN...

CHAPTER 5

THE ROLE OF "CONTEXT" IN LEXICAL PROCESSING OF HOMONYMS

5.1 Introduction

The aim of the experiments discussed in this chapter was to deepen the role of meaning frequency and grammatical class effects in lexical processing of ambiguous words. In the previous chapter I described some ambiguity effects in bare word recognition tasks depending on how different types of homonymous words are lexically represented and processed during lexical access. Even considering these variables again, the focus will be now on how grammatical class and frequency dominance interact with contextual information biasing towards one of two possible meanings of homonyms.

A number of approaches has been used to investigate lexical ambiguity in sentence processing. The question which inspired several experimental studies was to investigate how context operates, and at which stage of lexical processing. The classes of methods used to deal with this topic can be divided at least in three typologies: ambiguity detection, processing complexity tasks and priming paradigms (for a review, see Chapter 2). The most recent experimental evidence seems to reinforce the idea that both contextual information and meaning dominance effects play a role in lexical ambiguity resolution.

Little recent research has investigated the role played by the grammatical class of ambiguous words, manipulating the syntactic context and using a reading task. The general aim of this research line was to address the issue of whether lexical information guides interpretation independently from syntax (for a review, see Chapter 4).

Previous studies did not investigate the combined effects of grammatical class and meaning frequency and their interaction with contextual information in lexical ambiguity processing. Moreover, all studies which have addressed the issue of the role played by context were interested in understanding ambiguity resolution processes. For this reason, in studies carried out from 1980s and involving the priming technique, several methodological variations were used, such as the location of the ambiguous material, or the method of presentation of the context, but ambiguous words were always presented within a sentence, which could be either disambiguating or not. Upon the presentation of an ambiguous word, a target word was presented for a speeded response, usually in naming or lexical decision.

Since I was more interested in understanding the lexical representation and processing of ambiguous words rather than ambiguity resolution processes, in my experiments I have never implemented the priming paradigm using sentences, but single words. In my first two experiments, each homonymous word was preceded or followed by a single unambiguous word which could be semantically related or not to one of the two possible meanings of the homonym. In the other two experiments, I presented word-pairs which could be morphologically related or not.

As in the previous experiments, subsets of ambiguous words were selected, by manipulating the meaning frequency dominance and the grammatical class of the stimuli. A modulation of semantic and morphological priming effects was expected, depending on how different types of ambiguous words are lexically represented and processed during meaning access.

Before describing the experiments, a brief dissertation of both morphological and semantic priming paradigms will be presented.

The priming paradigm is widely used for disentangling the relative contribution of semantic and morphological factors in word recognition. In the paradigm a pair of stimuli is displayed with a varying interval of time, and the participant has to respond (for instance by taking a lexical decision) to the second stimulus, the target word. The prime can be unrelated or related to the target along one or more dimensions: it has been observed that the nature of the link between the two stimuli affects the recognition process.

The **semantic priming paradigm** represented a powerful tool for the investigation of the fundamental principles about the structure and processes of semantic memory (e.g., Ochsner, Chiu, & Schacter, 1994). In a typical version of this paradigm, participants are required to make a response (e.g., naming, lexical decision, semantic judgement) to a target stimulus, which is preceded by either an unrelated word or a semantically (and/or associatively) related word prime. Semantic priming is observed when responses to the target are faster and/or more accurate for the related than for the unrelated prime-target pairs.

An usual interpretation of semantic priming (e.g., Collins & Loftus, 1975) is that a prime stimulus (e.g., CAT) activates its corresponding internal representation (node) in memory, and such an activation spreads to other nodes linked in an associative network (Meyer & Schvaneveldt, 1971), thus facilitating the processing of related targets (e.g., DOG).

The *spreading activation theory* was unchallenged until Ratcliff and McKoon (1988) suggested that facilitative priming effects are the result of an associative match between prime and target in long-term memory. Like spreading activation, the *compound-cue retrieval theory* of priming predicts that priming depends on associative relations between the prime and the target, although the two models differ in their description of the processes which lead to facilitation. In contrast, theories of *distributed memory* focus on semantic similarity, an implicit feature of the overlap in featural representations or patterns of activation. Distributed models of word retrieval produce facilitation effects as a result of a decrease in the amount of time required to make a shift in semantic space between similar words (Kawamoto, 1988; Masson, 1991; 1995). In stark contrast with other models of priming, the dependence of the priming effect on semantic similarity is critical for distributed models of semantic memory.

These three models of priming – spreading activation, compound-cue, and distributed memory – all describe facilitation in terms of a passive, automatic process that reflects the organization of semantic memory. However, priming can also results from non-semantic factors, such as expectancies (Neely, 1977). Evidence for non-semantic facilitation has led to the formulation of a two-process theory of priming: a fast process that occurs automatically, without intention or conscious awareness; a slower, limited-capacity process requiring conscious attention (Posner & Snyder, 1975). Unlike automatic processes, controlled processes such as expectancy-based generation and postlexical matching do not necessarily reflects features of semantic organization or processing.

Several methods are known to minimize controlled influences on priming or to diagnose the relative degree of controlled processes. A short stimulus-onset asynchrony (SOA), a low proportion of related pairs (Tweedy, Lapinski, & Schvaneveldt, 1977), a pronunciation task instead of a lexical decision task (West & Stanovich, 1982) are all experimental manipulations that decrease the ability of participants or bias to use controlled mechanisms. In contrast, these manipulations have no effect on facilitation resulting from automatic processes.

Like semantic priming, the **morphological priming paradigm** has been widely investigated, as it sheds light on the role played by morphology in reading (see Drews, 1996; Feldman, 1994 for reviews). It refers to the facilitatory effect in recognizing a target word when it is preceded by a morphologically related word. A number of theoretical proposals have been advanced in order to account for morphological priming. In *decompositional accounts*, (e.g., Taft & Forster, 1975), reading a morphologically complex word involves parsing words into their constituents in order to access the lexicon. Thus, morphemes serve as the “access units” in reading, and morphologically related words are identified via the same access units. As a consequence, if the identification of a word results in the activation of a given access unit, the identification of other words sharing this unit (i.e., morphologically related words) will be facilitated for as long as this activation persists. In contrast, "*whole-word" account* of morphological priming (Butterworth, 1983; Grainger, Colé, & Segui, 1991; Feldman & Fowler, 1987; Fowler et al., 1985; Giraudo & Grainger, 2000; Schriefers, Friederici, & Graetz, 1992; Lukatela, Gligorijević, Kostić, & Turvey, 1980; Schriefers, Zwitserlood, & Roelofs, 1991) assume that, although each word has its own lexical entry, the lexicon is organized so that morphological relationships are explicitly represented (e.g., by direct links among the entries for morphologically related words). On this view, morphological priming occurs because the activation of a given word results in the partial activation of morphological related words, via their interconnections. A third kind of models combines decomposed accounts of lexical access with whole-word accounts (e.g., Caramazza, Laudanna, & Romani, 1988; Schreuder & Baayen, 1995). Even assuming a full decomposition model, it seems quite arbitrary to believe that a word, even morphologically complex, cannot be recognized as a whole, without decomposition. Recent empirical evidence reported in many languages seem to reinforce the hypothesis that the decomposition does not exclude lexical storage. In the *Augmented Addressed Morphology model* (AAM, Caramazza, Miceli, Silveri, & Laudanna, 1985) fully or partially irregular forms (e.g. 'went'), having no common base form that can be recovered from the input surface form, are represented independently. The morphological parsing procedure, instead, is activated in order to recognize infrequent words, neologisms, pseudowords, or never encountered words, which do not have a full representation and consequently need the recognition of their morphemes in order to be recognized. While the AAM model suggests that high frequency morphologically transparent words are processed through the access unit of the whole word, the *Morphological Race Model* (MR, Schreuder & Baayen, 1995) emphasizes the fact that the semantic transparency is crucial. Schreuder and Baayen assume that the meaning of complex words cannot be necessarily retrieved on the basis of the meanings of constituents. Like in the AAM model, in the MR model both full forms and morphemes are available routes, and it is not deterministically predictable which route will be adopted for the recognition: in the MR model the distinction between novel words and already encountered words is not so strong, and morphological structure does not necessarily guide the recognition. Each word leaves a trace in memory, irrespective of its morphological processing; the root and the word frequency effects are different and independent. Fully regular words also can leave their own trace in memory, and an inflected word can be also stored as full form, without default representations.

Semantic vs. morphological vs. orthographic priming effects. When we investigate morphological effects (for instance, priming effects between morphologically related words) we deal with the objection that prime-target pairs share a common meaning (Henderson, Wallis, & Knight, 1984). While semantic links between words are not always reflected in their orthography, it is generally true that words having a morphological relationship also have strong semantic (and orthographic) relationships. The morpheme is generally defined as the minimal unit of meaning. The economy of language leads to use compositional properties of morphemes: a morpheme can occur in several words with different degrees of variation in meaning. The traditional distinction is between inflection and derivation: derived and inflected forms differ with respect to the productivity of rules and the predictability of their meaning from a semantic analysis of the base and its constituents (Aronoff, 1976). Inflected forms are more consistent in meaning than derived forms, whose meaning may diverge from the one of their bases. Therefore, in studying morphological effects on visual word recognition, it is crucial to find conditions in which priming effects between morphologically related items occur in absence of priming effects tied up to semantics.

There are three relevant dimensions for semantic priming effects to arise: the density of semantically associated items in the experimental list, the lag, and the Stimulus Onset Asynchrony (SOA) between prime and target. Morphological effects occur and are long lasting when the density of morphologically related pairs is low (Napps, 1989). Semantic effects are also affected by the density (see Neely, 1977). The experimental list has to be neutral: if it contains numerous semantically related prime and target pairs, subjects unconsciously use a strategy of retrieval driven by meaning associations. A list composed only of words leads participants to use a lexical strategy: if pseudowords are inserted in the list, the semantic effect decays (Tabossi & Laghi, 1992). In the long-lag priming condition, where primes and targets are separated by a number of intervening stimuli, it has been observed that the magnitude of facilitation after morphologically related primes did not vary statistically across lags, while semantically related primes produce facilitation only at a 0-lag. (Bentin & Feldman, 1990). The use of intervening stimuli leads to a decay of the semantic priming effect, that is fully effective only when the target follows the prime. The morphological priming, even when is less strong than semantic priming in absence of intervening stimuli, endures when several items are included between prime and target. Fowler (reported in Feldman, 1991) used an experimental list in which a target (e.g., HOT) was preceded by ten intervening items and then, by the same item (e.g. HOT) or by an antonym (e.g., COLD). No semantic facilitation between the antonyms was found. Nevertheless, morphological effects occur when prime and target are supported by a lag that considerably exceeds those at which semantic/associative priming has been demonstrated (Bentin & Feldman, 1990; Napps, 1989).

As to dimensions of SOA, one possibility is to use masked priming: Frost, Forster & Deutsch, (1997), employed a forward-masking paradigm in a visual lexical decision task on Hebrew words, and showed that morphological facilitation does not coincide with an effect of semantic relatedness. The morphological facilitation occurs also with intervals longer than those observed with semantic facilitation: Feldman (2000) showed that both semantic and morphological facilitations occur at an interval of thirty-two milliseconds between prime and target, but only the purely morphological facilitation persists at three hundred milliseconds. Several studies confirmed this effect of morphological facilitation. The common explanation is that if two words are morphologically related, they share at least part of their mental representation and the lexical decision on the target is facilitated. A slightly different hypothesis is that in the mental lexicon the lexical units are connected by means of morphological links. When the prime is accessed, morphologically related words are activated. For instance, the presentation of an inflected verbal form facilitates the recognition of its base, and this facilitation is comparable with the effect obtained in the identity priming condition; the same effect occurs with base forms primed by derived forms. Both explanations support the idea that the two stimuli share a common key to reach the lexicon, and that this key is morphology-specific. Even if we maintain that morphological and semantic facilitation reflect different underlying mechanisms, a further problem concerns the role of orthography. Morphologically related forms share some orthographic material, and morphological priming could be a product of orthographic priming (Seidenberg, 1987). Nevertheless, the research in this area has demonstrated that morphological priming can be distinguished from purely semantic or purely orthographic priming. Morphologically related pairs produce more durable and stronger facilitation than semantic priming, whereas orthographically related pairs produce no facilitation or even inhibitory effects (Henderson et al., 1984; Murrel & Morton, 1974; Napps, 1989; Napps & Fowler, 1987). Moreover, the use of homographic stems serves the purpose to disentangle the relative role of morphology in lexical access. Stem homographs are words with stems that are orthographically identical but morphologically unrelated. For example, in Italian the stems of ‘colp-ire’, *to hit*, and ‘colp-a’, *guilt*, are orthographically identical, but different in meaning. The use of homographic stems (Laudanna, Badecker, & Caramazza, 1992) suggested that the orthographic and morphological representations are differently organized: an inhibitory effect for stem homograph pairs and a facilitatory effect for morphologically related words were found for the two conditions.

5.2 Semantic cues and meaning frequency dominance in processing of homonyms

5.2.1 Introduction

It is not a matter of recent debate that contextual information plays a role in ambiguity resolution processes. In normal reading, speakers continuously encounter ambiguous words inserted within sentences which bias towards one of two alternative interpretations. In this situation, the recourse both to context information and world knowledge allows to resolve the ambiguities without problems. The question that inspired these experiments was to understand how the semantic context operates in the lexical processing of ambiguous words and especially how it interacts with some variables which have been demonstrated to be crucial in determining different ambiguity effects:

- the grammatical status of ambiguous words;
- the meaning frequency dominance.

As in the previous experiments, the investigation was restricted to ambiguous words with two unrelated words (namely, homonyms). I carried out two naming experiments involving the semantic priming paradigm, where ambiguous words were presented either in target (Exp.5) or in prime position (Exp.6). In both the experiments, ambiguous words were not inserted in a sentence context, but only preceded or followed by a single word, either semantically related or unrelated. I also avoided experimental tasks directly requiring a recourse to semantic information (e.g., semantic categorization tasks). I preferred to adopt the naming task rather than the lexical decision task in order to decrease the recourse to strategic, post-lexical mechanisms which may occur in a semantic priming paradigm (West & Stanovich, 1982).

By manipulating the meaning frequency dominance and the grammatical class, a modulation of semantic facilitation priming was expected, depending on whether ambiguous words were primed or followed by words biasing towards their dominant, subordinate or balanced meaning. Furthermore, I expected processing differences also depending on the grammatical status of homonyms. If a well-established effect such as the semantic priming facilitation was affected by these manipulations, the result could reinforce the idea of a crucial role played by these variables in determining different ambiguity effects, even in presence of some "contextual" information.

5.2.2 Experiment 5

5.2.2.1 Method

Stimuli. Ninety homonymous words from the same database used for Experiment 1 and 2 were selected and split in five subsets:

- 18 were more frequent as nouns (N>V e.g., *abito*, dress/I live);
- 18 were more frequent as verbs (V>N e.g., *accetta*, he/she accepts/hatchet);
- 18 had two balanced nominal meanings, (N=N e.g., *credenza*, cupboard/belief);
- 18 had two unbalanced nominal meanings (N>N e.g., *campione*; champion/sample);
- 18 had two balanced nominal/verbal meanings (N=V e.g., *costa*, coast/it costs).

In experimental conditions homonyms were primed by semantically related primes (e.g. *mare→costa,* sea→coast/it costs*);* in the control condition they were preceded by unrelated primes (e.g., *miele→costa*, honey→coast/it costs. In order to create prime-target pairs with the same degree of semantic association, I used the results of the off-line meaning generation task submitted for the Experiments 1 and 2. Firstly, only the ambiguous words for which at least the 80% of subjects had listed both the meanings were used. Secondly, each subset of ambiguous words was matched for the mean value reported on the Likert 1-7 scale semantic association task. For each subset of ambiguous words I obtained a subset of unambiguous nouns always related to the nominal meaning of ambiguous targets. As far as the N>N forms are concerned, I obtained two subsets of unambiguous primes, respectively related to the dominant and the subordinate meaning of homonyms; as far as the N=N forms, I used as prime the words that had received the biggest association values. In Table 5.1 the mean semantic association values of the data set are shown.

	Example	**Mean semantic association**
N>V	vestito - abito	4.7
V>N	bocca - saliva	4.6
N=N	religione - credenza	4.7
N>N	vittoria - campione	4.7
N<N	indagine - campione	4.5
N=V	febbre - supposta	4.8

Table 5.3. Mean semantic association values of each subset of prime-target pairs

Each subset of related primes was compared to a subset of unrelated primes for their mean frequency and length (in number of letters, syllables and phonemes). In Table 5.2 the mean values of the data set are reported.

	Frequency	**Letters**	**Syllables**	**Phonemes**
Related primes	134	7	3.1	6.5
Unrelated primes	136	6.9	3	6.5

Table 5.4. Mean frequency and length values in Experiment 5.

The whole experimental list is reported in Appendix. Two hundred fifty-two prime-target pairs were included in the list as fillers. All the filler words were real unambiguous words, matched with experimental targets for their mean length (in number of letters) and frequency.

Experimental session. The whole experiment was arranged in two different sessions, each containing three hundred sixty prime-target pairs. In each session all targets were shown, but each target was presented only once in one of the two experimental conditions (either preceded by the related prime or by the unrelated prime). The two different conditions were

equally distributed in the two sessions. Each session was divided in five blocks: each block was composed of seventy-two items.
Five randomizations for the order of presentation of the blocks and two randomizations for increasing and decreasing alphabetic order of presentation of the stimuli in each block were created.

Participants. Forty participants, all students of the University of Salerno, and native speakers of Italian, took part into the experiment. They served for a session lasting about thirty minutes. Each participant was submitted to a single experimental session. Each pair of two participants constituted one data point in the statistical analyses.

Equipment. Microphone and sound recorder, connected to an IBM PC running the E-Prime software (Version 1.1).

Procedure. A naming task was used as experimental paradigm, employing the technique of unmasked priming (Figure 5.1). Participants were asked to read aloud the second word of each pair presented on the screen as fast and accurate as possible. The experiment was preceded by a practice session.
All the stimuli appeared in Courier New font, 18 point size in the centre of the computer screen. The fixation was set at 300 ms, followed by a 300 ms pause. Primes appeared for 200 ms, followed by a 50 ms pause. The targets remained on the computer screen for a maximum of one second. If the participants did not produce any answer within one second, the feedback 'Fuori tempo' (Out of time) appeared on the screen.

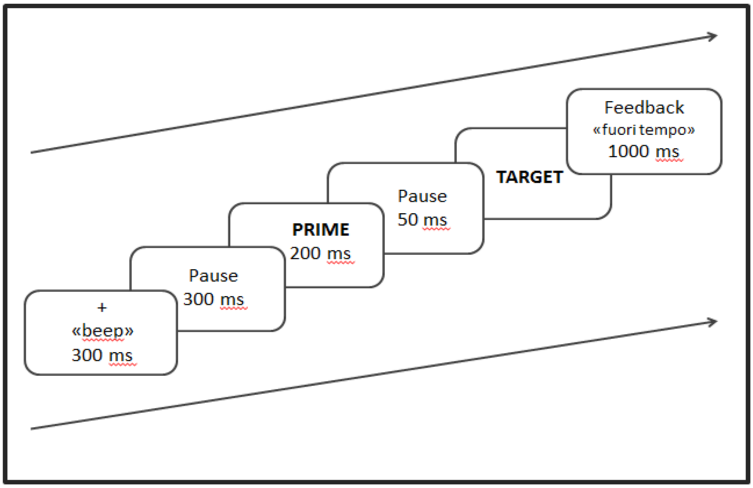

Figure 5.2. Unmasked priming procedure

The reaction times and the errors were the dependent variables. The reaction times were measured from onset to the response, and the lack of a response was scored as an error. As the microphone connected to the computer measured only the reaction times, all the hesitations and reading errors were recorded and manually reported for the statistical analysis.

5.2.2.2 Results and Discussion

In Table 5.3 mean reaction times, percentage of errors and size of condition effects are shown.

	Control condition	Experimental condition	Condition effect
Reaction times	534	520	-14
Errors	2.2	3	+0.8

Table 5.3. Mean correct naming latencies (in milliseconds), percentage of errors and condition effects.

The ANOVA on response latencies revealed a significant condition effect (ANOVA by participants $F(1,39)=20.04$; $p<.001$; ANOVA by item

F(1,196)=10.2; p<.001). The ANOVA on error data showed an approximate significance for condition only in the ANOVA by items (F(1,196)=3.22; p<.07; ANOVA by participants F(1,39)=1.33).

In Table 5.4 mean reaction times and percentage of errors of each subset of experimental and control items are shown. Table 5.5 shows the size of condition effects in response latencies and percentage of errors.

	Control condition	**Experimental condition**
N>V	539 (3.6)	517 (5)
V>N	533 (1.1)	532 (1.4)
N=N	536 (1.4)	513 (2.5)
N>N	533 (4.2)	517 (4.2)
N<N	529 (1.1)	523 (1.9)
N=V	538 (1.9)	522 (3.3)

Table 5.4. Mean correct naming latencies and percentage of errors in each subset of stimuli

N>V	- 22 ms (+1.4%)
V>N	- 1 ms (+0.3%)
N=N	- 23 ms (+1.1%)
N>N	- 16 ms (0%)
N<N	- 6 ms (+0.8%)
N=V	- 16 ms (+1.4%)

Table 5.5. Condition effects of each subset in response latencies. In parentheses the effects on errors.

Post-hoc analyses based on the ANOVA by participants on response latencies showed a significant difference between the experimental and control condition in N>V (p<.01), N=N (p<.005), N>N (p<.05), and in N=V (p<.01), but not in the other subsets (V>N: p<.9; N<N: p<.4).

In Figure 5.2 mean reaction times of each subset of experimental and control items are graphically shown; significant differences in post-hoc analyses are highlighted.

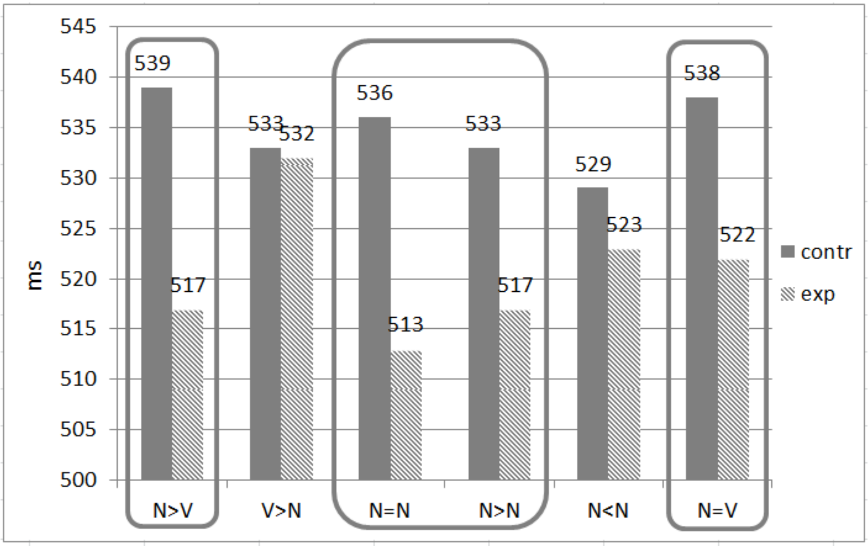

Figure 5.3. Mean reaction times in each subset of items

Post-hoc analyses based on the ANOVA by participants on error data did not reveal any significant difference between the experimental and control condition (N>V: p<.3; V>N: p<.8; N=N: p<.4; N>N: p<.8; N<N: p<.5; N=V: p<.3).

In Figure 5.3 percentages of errors of each subset of experimental and control items are graphically shown.

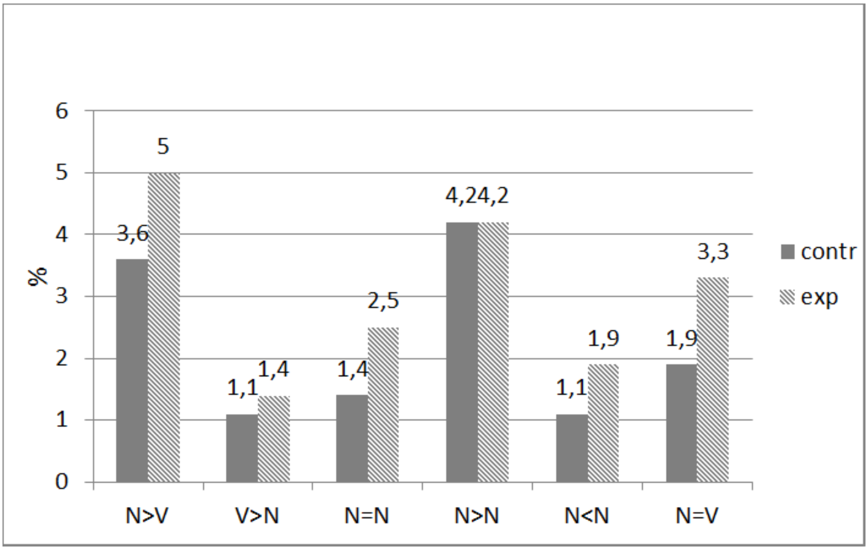

Figure 5.3. Percentage of errors in each subset of items

The overall results of Experiment 5 reveal a significant condition effect: when ambiguous targets are primed by semantically related words there is an advantage both in speed and accuracy of naming. Nevertheless, single comparisons reveal a complex pattern of results in RT analyses: a significant condition facilitation is reported when homonymous targets are primed by words related to the dominant meaning (N>V and N>N) or to one of two possible balanced meanings (N=N and N=V); no effect is observed when targets are primed by words semantically related to the less frequent meaning (V>N and N<N). The results seem to confirm that there is a modulation of the semantic facilitation due to the meaning frequency dominance of ambiguous words. No processing differences are reported according to the grammatical class of ambiguous words. However, the fact the ambiguous words were presented in target position, preceded by primes always related to their nominal meaning, could have annulled grammatical class effects. The next step is to investigate what happens if the order of presentation of prime and target is reversed; in this way, the focus will be mainly on the multiple meaning activation procedures. Presented in prime position, ambiguous forms are processed

before any "contextual" information; thus, if grammatical class and meaning frequency dominance actually play a role in lexical processing of homonyms, different types of ambiguous forms should differently prime their targets.

5.2.3 Experiment 6

5.2.3.1 Method

Stimuli. The homonymous items were the same used in Experiment 5, but the order of presentation of prime and target was reversed (e.g., *costa→mare,* coast/it costs→sea in the experimental condition; *vino→mare*, wine→sea). Differently from Experiment 5, for N=N forms two subsets of unambiguous targets were obtained, respectively related either to one meaning or to the other one of homonyms. In order to obtain prime-target pairs with the same semantic association degree, a Likert-scale rating was carried out, with the order of presentation of the words reversed. In Table 5.6 mean semantic association values of the data set are shown.

	Example	**Mean semantic association**
N>V	abito - vestito	5.1
V>N	saliva - bocca	5
N=N$_1$	credenza - religione	5
N=N$_2$	credenza - armadio	4.9
N>N	campione - vittoria	4.9
N<N	campione - indagine	4.9
N=V	supposta - febbre	5

Table 5.6. Mean semantic association values of each subset of prime-target pairs

Each subset of homonymous related primes was compared to a subset of unambiguous unrelated primes, belonged to the same grammatical class of the more frequent meaning of ambiguous words. Specifically, the experimental N>V, N=N and N>N forms were matched with unambiguous nouns, while the V>N forms were matched with unambiguous verbs. Finally, the N=V forms – where there is not a dominant grammatical class - were compared to a subset half-made by unambiguous nouns and half-made by unambiguous verbs. In Table 5.7 the mean values of the data set are reported.

	Frequency	**Letters**	**Syllables**	**Phonemes**
Related primes	71	5.9	2.5	5.4
Unrelated primes	67	5.9	2.5	5.6

Table 5.7. Mean frequency and length values in Experiment 6.

The whole experimental list is reported in Appendix. Two hundred fifty-two prime-target pairs were included in the list as fillers. All the filler words were real unambiguous words, matched with experimental targets for their mean length (in number of letters) and frequency.

Experimental session. The whole experiment was arranged in two different sessions, each containing three hundred sixty prime-target pairs. In each session there were all the targets, but each target was presented only once in one of the two experimental conditions (either preceded by the related ambiguous prime or by the unrelated unambiguous prime). The two different conditions were equally distributed in the two sessions. Each session was divided in five blocks: each block was composed of seventy-two items. Five randomizations for the order of presentation of the blocks and two randomizations for increasing and decreasing alphabetic order of presentation of the stimuli in each block were created.

Participants. Forty participants, all students of the University of Salerno, and native speakers of Italian, took part into the experiment. They served for a session lasting about thirty minutes. Each participant was submitted to a single experimental session. Each pair of two participants constituted one data point in the statistical analyses.

Equipment and *procedure* were the same as in Experiment 5.

5.2.3.2 Results and Discussion

In Table 5.8 mean reaction times, percentage of errors and size of condition effects are shown.

	Control condition	Experimental condition	Condition effect
Reaction times	515	506	-10
Errors	2.7	3.2	+0.5

Table 5.8. Mean correct naming latencies (in milliseconds), percentage of errors and condition effects.

The ANOVA on response latencies revealed a significant condition effect (ANOVA by participants $F(1,37)=10.58$; $p<.005$; ANOVA by item $F(1,204)=3.76$; $p<.05$). The ANOVA on error data did not show any significant effect (ANOVA by participants $F(1,37)=1.60$; ANOVA by items $F(1,204)=.89$).
In Table 5.9 the mean reaction times and percentage of errors of each subset of experimental and control items are shown. Table 5.10 shows the size of condition effects in response latencies and percentage of errors.

	Control condition	Experimental condition
N>V	529 (2.5)	512 (4.7)
V>N	508 (1.3)	507 (1.6)
N=N	508 (3.4)	507 (2.8)
N=N_2	521 (1.6)	515 (2.3)
N>N	520 (5.9)	496 (3.4)
N<N	505 (2.3)	506 (5)
N=V	515 (1.3)	497 (2.3)

Table 5.9. Mean correct naming latencies and percentage of errors in each subset of stimuli

N>V	- 17 ms (+2.2%)
V>N	- 1 ms (+0.3%)
N=N	- 1 ms (-0.6%)
N=N_2	- 6 ms (+0.7%)
N>N	- 24 ms (-2.5%)
N<N	+ 1 ms (+2.7%)
N=V	- 18 ms (+1%)

Table 5.10. Condition effects of each subset in response latencies. In parentheses the effects on errors.

Post-hoc analyses based on the ANOVA by participants on response latencies showed a significant difference between the experimental and control condition in N>V ($p<.02$), N>N ($p<.003$), and in N=V ($p<.003$), but not in the other subsets (V>N: $p<.9$; N=N: $p<.9$; N=N_2: $p<6$; N<N: $p<.4$).
In Figure 5.4 mean reaction times of each subset of experimental and control items are graphically shown; significant differences in post-hoc analyses are highlighted.

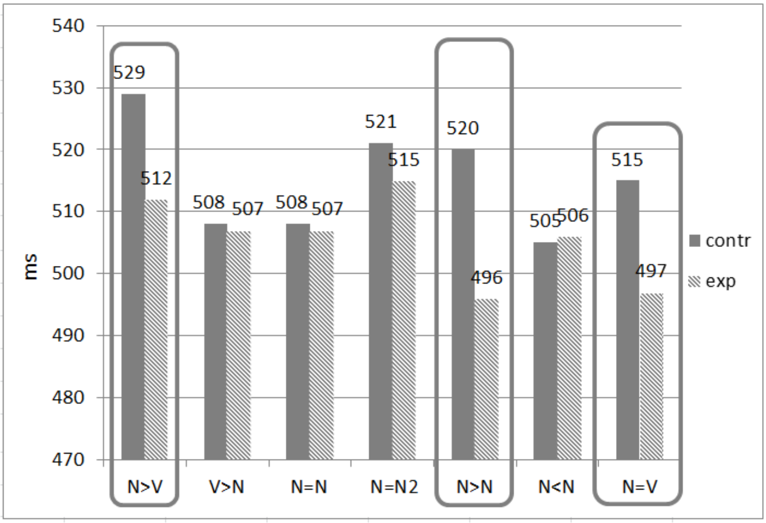

Figure 5.4. Mean reaction times in each subset of items

Post-hoc analyses based on the ANOVA by participants on error data revealed a significant difference between the experimental and control condition in N>V ($p<.05$), N>N ($p<.05$), and in N<N ($p<.05$), but not in the other subsets (V>N: $p<.1$; N=N: $p<.8$; $N=N_2$: $p<5$; N=V: $p<3$).

In Figure 5.5 percentages of errors of each subset of experimental and control items are graphically shown; significant differences in post-hoc analyses are highlighted.

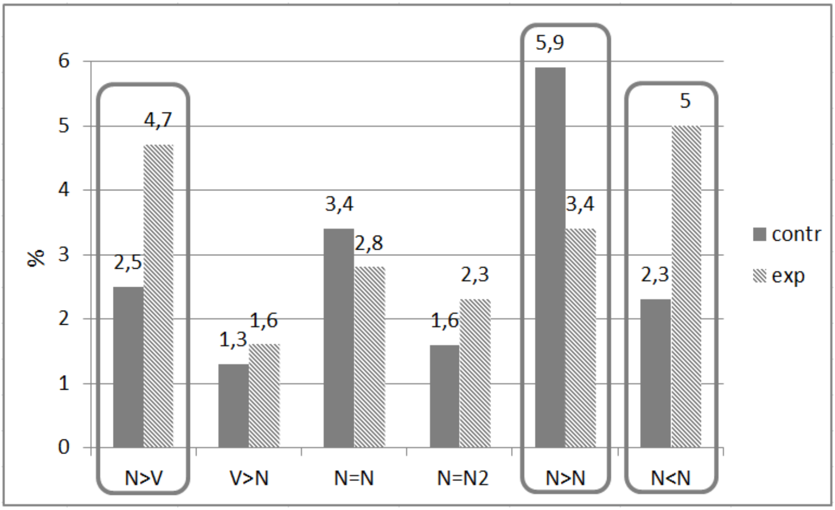

Figure 5.5. Percentage of errors in each subset of items

The overall results of Experiment 6 reveal a significant condition effect only in latencies: when targets are preceded by semantically related ambiguous primes they are recognized faster than in the unrelated condition. Nevertheless, single comparisons reveal a complex pattern of results in RT analyses: a significant condition facilitation is always reported when ambiguous words primed targets with their dominant meaning (N>V and N>N); in contrast, no facilitatory effect was observed when homonyms primes were related to targets with their less frequent meaning (V>N and N<N). As to balanced ambiguous forms, a significant condition effect is reported only with N=V forms in prime position, but not with N=N and $N=N_2$ forms.

The results confirm a modulation of the semantic facilitation due both to the meaning frequency dominance and to the grammatical class of ambiguous words. Differently from Experiment 5, here processing differences between balanced noun-noun homonyms and noun-verb homonyms are reported. Whereas N=N and $N=N_2$ forms did not facilitate targets, N=V forms did. The pattern can be interpreted as a further evidence of the so-called *nominal dominance* hypothesis, which predicts that frequency-equal ambiguous forms without context information are accessed as nouns by default. Thus, although noun-verb forms are balanced homonyms as noun-noun forms, in the first case there is a greater probability that these forms are accessed as nouns and, consequently, facilitate targets which are semantically related to their nominal meaning. In the second case, both meanings are nominal and, moreover, balanced, so there is actually the same activation probability of either the related or the unrelated meaning.

5.2.4 Discussion

In this phase of my research I was interested in investigating the lexical processing of ambiguous words by taking into consideration the role of "contextual" information. Specifically, the question which inspired my experiments was to understand how grammatical class and meaning frequency dominance information interact with semantic information biasing towards one of two possible meanings on homonyms. The results of Experiments 5 and 6 confirmed that these variables seem to play a crucial role in how multiple meanings are lexically processed, even in presence of context.

Depending on the meaning frequency dominance, homonyms could be semantically related to the unambiguous prime/target word with either their dominant meaning, their subordinate meaning or one of their frequency-equally meanings. According to the grammatical class, the unrelated meaning of homonyms could be either nominal (e.g., *campione→vittoria*) or verbal (e.g., *abito→indumento*).

In both experiments when targets were preceded by semantically related primes they were recognized faster than in the unrelated condition. At a first glance, this result could be interpreted as an evidence that the well-established semantic priming effect is always reported, independently from the ambiguity status of words adopted either as primes or targets. Actually, the experimental design obtained by manipulating grammatical class and meaning frequency dominance of homonyms allowed us to observe a more complex pattern.

Specifically, in Experiment 5 the condition effect was reported always in the case of balanced homonyms.

When homonymous targets were unbalanced, the facilitation effect was reported only when the primes were related to their dominant meaning but not when they were related to their subordinate meaning.

In contrast, for balanced words, the prime strengthened the meaning which was related to, blocking the activation of the competitive unrelated meaning.

A slightly different result pattern was obtained in Experiment 6, where the meaning activation of ambiguous words preceded the presentation of the semantic information. Unbalanced words exhibited the same behaviour reported for these forms in Experiment 5: a facilitatory effect when they primed towards targets with their dominant meaning; no effect in the case of subordinate meaning.

As to balanced homonyms, processing differences were reported between noun-noun words and noun-verb words. The semantic facilitation was found only for N=V forms, which primed targets with their nominal meaning. Even though these forms are frequency-equal homonyms, the nominal meaning in isolation is more likely to be activated than the verbal meaning. This datum is compatible with the results reported in the grammatical decision experiment, where N=V forms were assigned significantly more often to the nominal class by subjects (see Paragraph 4.2 Experiment 3 of this thesis).
The following step of my work was to investigate how morphological information operates in the lexical processing of ambiguous words. Specifically, the question which inspired the next two experiments was to evaluate if grammatical class and meaning frequency dominance play a role even in presence of information morphologically related to one of two possible entries of homonyms.

5.3 Morphological activation and meaning frequency dominance in processing of homonyms

5.3.1 Introduction

Over the past 20 years, psycholinguistic research on lexical ambiguity resolution provided a large body of evidence as well as theoretical accounts about the fact that meaning frequency dominance and context affect access procedures, with interesting implications for language processing.
The aim of the following experiments was to assume a slightly different view on contextual information and focus on morphological variables which could play a role in lexical processing of ambiguous words. The question was to understand how morphological information operates in the lexical retrieval and especially how it interacts with the meaning frequency dominance which has been demonstrated to be one of most crucial variables in determining different ambiguity effects.

As in previous experiments, I restricted my investigation to ambiguous words with two unrelated words (homonyms). I carried out two lexical decision experiments involving the morphological priming paradigm in which ambiguous words were presented either in target (Exp.7) or in prime position (Exp.8). In both the experiments, ambiguous words were not included in a sentence context, but only preceded or followed by a single word, morphologically related or unrelated. By manipulating the meaning frequency dominance, I expected a modulation of morphological facilitation priming depending on whether ambiguous words were primed or followed by verbs related to their verbal entry, which was dominant, subordinate or balanced with respect to the nominal entry. Differently from semantic priming experiments, homonymous words were always morphologically and semantically related with their verbal meaning to the unambiguous verbs used either as primes or targets (e.g., *abitata*→*abito* and vice versa). The noun-noun ambiguous words were excluded from the investigation, by selecting only the ambiguous words with a nominal and a verbal meaning. If a well-established effect such as the morphological priming facilitation was affected by this manipulation, the result could reinforce the idea of a crucial role played by meaning frequency dominance, even in presence of some "contextual" information.
A similar study involving the morphological paradigm was carried out on Italian polysemous past participles (Postiglione & Laudanna, submitted), which were either more frequent as nouns (*impiegato* clerk/employed, N>V) or as verbs (*condannato* condemned/convict, V>N). In two lexical decision experiments, these forms were preceded or followed by morphologically related forms (e.g. impiegava→impiegato and vice versa). The morphological facilitation effect was found on both subsets of stimuli, even though it was stronger on N>V forms. The result was interpreted as an evidence that these forms do not share the lexical representation, due to their different syntactic roles.
However, the most important difference with my experiments is that the forms used by the authors had related meanings. Thus, the verbs used either as primes or targets were morphologically and semantically related to both entries of polysemous words. In my study, the verbal forms were

morphologically (and semantically) related only to the verbal entry, due to the specific nature of the homonymy. As a result, the verbal forms and the nominal entry of my experimental stimuli were only orthographically related. Specifically, they were stem-homographs, namely words with stems that are orthographically identical but morphologically unrelated. As reported in the introduction of this chapter, the orthographic priming paradigm never revealed a facilitation effect. Moreover, the stem-homography effect was inhibitory rather than facilitatory. Differently from homonymous words, which had two unrelated meanings, the forms adopted by Postiglione and Laudanna were only grammatically ambiguous. In an online grammatical decision task on these forms, they found a strong bias to nominal assignment, even though the forms were more frequent as verbs. The result was interpreted as an evidence of the idea that when words are presented in isolation, they are lexically accessed as nouns "by default". The meaning frequency effect seems to play a weaker role on these forms, presumably because all representations are connected each other and share a unique core meaning. It results that they are all activated in lexical processing, independently by their frequency distributions.

5.3.2 Experiment 7

5.3.2.1 Method

Stimuli. Fifty-one homonyms were selected from the same database used for Experiments 1 and 2and split in three subsets:

- 17 words were more frequent as nouns (N>V e.g., *abito*, dress/I live);
- 17 words were more frequent as verbs (V>N e.g., *accetta*, he/she accepts/hatchet);
- 17 words had two balanced nominal/verbal meanings (N=V e.g., *costa*, coast/it costs).

In the experimental condition homonyms were presented as targets, preceded by morphologically related primes, always biasing towards the verbal meaning of homonyms (e.g., *abitata→abito,* lived→dress/I live). The primes biased towards dominant, balanced or subordinate meaning, depending on the meaning frequency dominance of each subset of homonyms.

In the control condition, ambiguous words were preceded by unrelated primes (e.g., *rivelata→abito,* revealed→dress/I live). In order to create prime-target pairs with the same degree of orthographic overlap, the three subsets were matched for the number of letters shared between primes and targets, considered on the average of length of primes and targets (N shared letters). I also considered the number of letters in common in the same position within the word (N shared letters same position). In Table 5.11 mean orthographic overlap of the data set is shown.

	Example	**N shared letters**	**N shared letters same position**
N>V	abitata - abito	0.76	0.76
V>N	salire - saliva	0.77	0.76
N=V	costava - costa	0.76	0.76

Table 5.11. Mean orthographic overlap of each subset of prime-target pairs

Each subset of related primes was compared to a subset of unrelated primes for their mean frequency and length. In Table 5.12 the mean values of the data set are reported.

	Frequency	**Number of letters**
Related primes	23	7.2
Unrelated primes	22	7.1

Table 5.12. Mean frequency and length values in Experiment 7.

The whole experimental list is reported in Appendix. Two hundred sixty-nine prime-target pairs were included in the list as fillers. Thirty of these pairs were composed by real unambiguous words used as primes and targets (W-W). The other filler pairs were constructed as follows:

- 80 non word prime – word target pairs (NW-W);
- 79 word prime – non word target pairs (W-NW);
- 80 non word prime – non word target pairs (NW-NW)

Thirty-six W-NW pairs were orthographically related, in order to seem similar to experimental condition (e.g., *chiudevo→chiure*, I closed→non word). All the real words used in the filler pairs were unambiguous words, matched with experimental items for their mean length and for their frequency; half of the fillers were nouns and half were verbs.

Experimental session. The whole experiment was arranged in two different sessions, each containing three hundred twenty prime-target pairs. In each session all the fifty-one ambiguous targets were used, but each target was presented only once in one of the two experimental conditions (either preceded by the related prime or by the unrelated prime).
The two different conditions were equally distributed in the two sessions. Each session was divided in five blocks: each block was composed of sixty-four items. Five randomizations for the order of presentation of the blocks and two randomizations for increasing and decreasing alphabetic order of presentation of the stimuli in each block were created.

Participants. Forty participants, all students of the University of Salerno and native speakers of Italian, took part into the experiment. They served for a session lasting about twenty minutes. Each participant was submitted to a single experimental session. Each pair of two participants constituted one data point in the statistical analyses.

Equipment. Response box, connected to an IBM PC running the E-Prime software (Version 1.1).

Procedure. A visual lexical decision task was used as experimental paradigm, employing the technique of unmasked priming (as in Experiments 5 & 6). The experiment was preceded by a practice session. Participants were asked to make a decision as fast and accurate as possible. They had to press on two buttons: the button corresponding to their dominant hand for the decision 'word', the other for the decision 'non-word'. When the participants reached the 70% of correct responses in the practice session, the experiment started. All the stimuli appeared in Courier New font, 18 point size in the centre of the computer screen. As in semantic priming experiments 5 & 6, primes appeared for 200 ms, followed by a 50 ms pause.

The targets remained on the computer screen for a maximum of one second. If the participants did not produce any answer within one second, the feedback 'Fuori tempo' (Out of time) appeared on the screen.

The reaction times and the errors constituted the dependent variables. The reaction times of right responses were measured from item onset to response of subjects, while the lack of a response was scored as an error, as the wrong responses.

5.3.2.2 Results and Discussion

In Table 5.13 mean reaction times, percentage of errors and size of condition effects are shown.

	Control condition	**Experimenta l condition**	**Condition effect**
Reaction times	555	532	-23
Errors	6.8	4	-2.8

Table 5.13. Mean correct LD latencies (in milliseconds), percentage of errors and condition effects

The ANOVA on response latencies revealed a significant condition effect (ANOVA by participants $F(1,20)=19.99$; $p<.001$; ANOVA by item

$F(1,96)=8.40$; $p<.005$). Also the ANOVA on error data showed a significant effect (ANOVA by participants $F(1,20)=9.26$; $p<.005$; ANOVA by items $F(1,96)=4.42$; $p<.05$).

In Table 5.14 the mean reaction times and percentage of errors of each subset of experimental and control items are shown. Table 5.15 shows the size of condition effects in response latencies and percentage of errors.

	Control condition	**Experimental condition**
N>V	560 (7.6)	540 (5)
V>N	554 (8)	523 (2.3)
N=V	550 (4.4)	534 (4.7)

Table 5.14. Mean correct LD latencies and percentage of errors in each subset of stimuli

N>V	- 20 ms (-2.6%)
V>N	- 31 ms (-7.7%)
N=V	- 16 ms (+0.3%)

Table 5.15. Condition effects of each subset in response latencies. In parentheses the effects on errors.

Post-hoc analyses based on the ANOVA by participants on response latencies showed a significant difference between the experimental and control condition in all subsets: N>V ($p<.005$), V>N ($p<.001$), and in N=V ($p<.05$).

In Figure 5.6 mean reaction times of each subset of experimental and control items are graphically shown; significant differences in post-hoc analyses are highlighted.

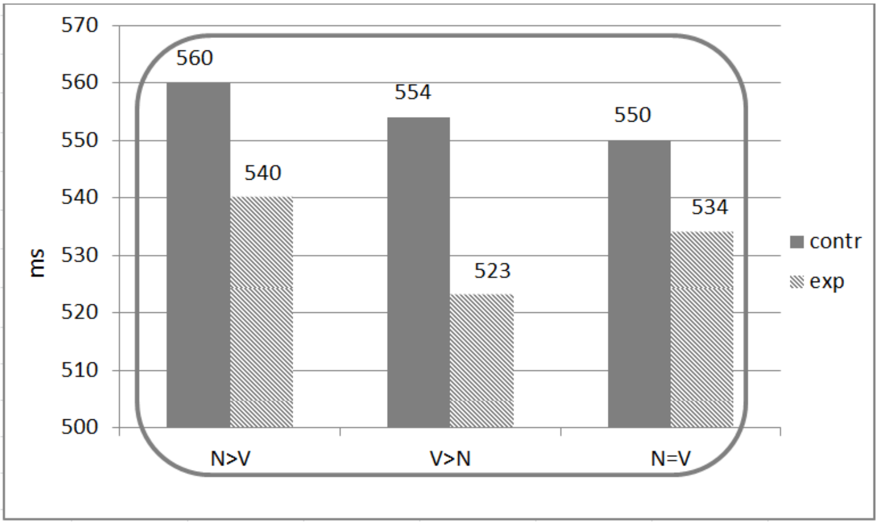

Figure 5.6. Mean reaction times in each subsets of items

Post-hoc analyses based on the ANOVA by participants on error data revealed a significant difference between the experimental and control condition in V>N (p<.003), but not in the other subsets (N>V: p<.1; N=V: p<8).

In Figure 5.7 percentages of errors of each subset of experimental and control items are graphically shown; significant differences in post-hoc analyses are highlighted.

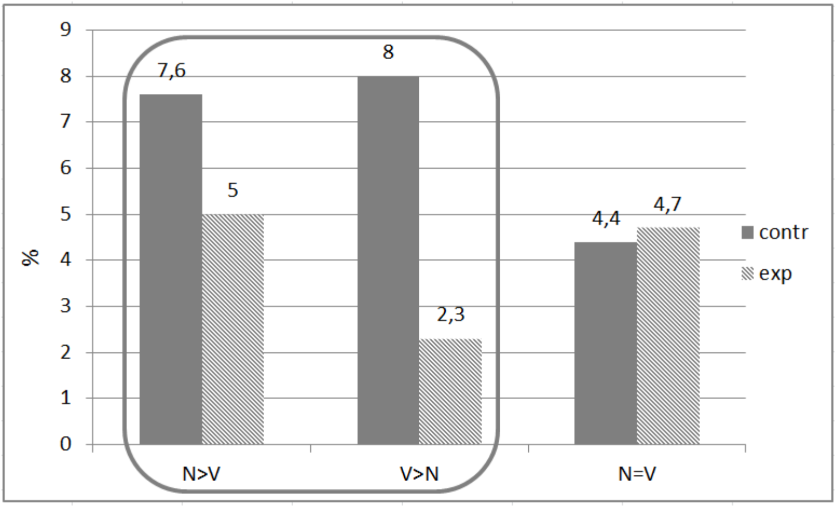

Figure 5.7. Percentage of errors in each subset of items

The overall results of the Experiment 7 reveal that when homonyms are preceded by morphologically related primes they are recognized faster and better than in the unrelated condition. Furthermore, single comparisons reveal a similar pattern of results in RT analyses: a significant morphological facilitation is reported in each subset of homonyms, independently from the meaning frequency dominance. However, the priming effect is stronger when primes are related to the most frequent meaning of the homonyms (V>N forms). As to error percentages, the morphological facilitation is found only on V>N forms, consistently with the frequency dominance of these forms.

Differently from the experiments involving the semantic priming paradigm, the morphological priming seems to be less affected by the meaning frequency effect. This is compatible with the evidence on morphological priming effects, which demonstrated how facilitatory effects due to morphological features are generally more long-lasting and resistant than semantic ones (e.g., Bentin & Feldman, 1990; Napps, 1989). However, the presentation of ambiguous words in target position could have weakened the frequency dominance effects. The verbal entry of ambiguous words could be had pre-activated by the morphologically related prime, even in the subordinate condition (N>V forms).

By reversing the order of presentation of prime and target (Exp. 8), I expect a more determining role played by the meaning frequency dominance in modulating the morphological priming effect.

5.3.3 Experiment 8

5.3.3.1 Method

Stimuli. The homonyms[43] were the same as in Experiment 7, but the order of presentation of prime and target was reversed. In the experimental condition homonyms were presented as primes, followed by morphologically related targets, biased always from the verbal meaning of

[43] In this experiment each subset was composed by 18 ambiguous forms, one more than in Experiment 7.

ambiguous primes (e.g., *abito→abitata,* dress/I live→lived). The primes biased with their dominant, balanced or subordinate meaning towards targets, depending on their meaning frequency dominance. In the control condition, targets were preceded by unambiguous unrelated primes (e.g., *penso→abitata* I think→lived). Differently from Experiment 7, I added a condition where targets were preceded by morphologically related unambiguous primes (e.g., *abita→abitata*, he/she lives→lived). From now on, I will call this condition "morphological", in order to distinguish it from the experimental condition. In order to create prime-target pairs with the same degree of orthographic overlap, the three subsets were matched for the number of letters shared between primes and targets, calculated with the same procedure used for Experiment 7. The orthographic overlap was matched also for the morphological condition. In Table 5.16 mean orthographic overlap of the data set is shown.

	EXPERIMENTAL CONDITION			**MORPHOLOGICAL CONDITION**		
	Example	**Shared letters**	**Shared letters same position**	**Example**	**Shared letters**	**Shared letters same position**
N>V	abito - abitata	0.77	0.77	abita - abitata	0.77	0.77
V>N	saliva - salire	0.74	0.74	salito - salire	0.74	0.74
N=V	costa - costava	0.76	0.76	costare - costava	0.76	0.76

Table 5.16. Mean orthographic overlap of each subset of prime-target pairs

Each subset of ambiguous primes was compared to either the subset of related unambiguous primes and unrelated primes for their frequency and length range. In Table 5.17 the mean values of the data set are reported.

	Frequency	Number of letters
Related ambiguous primes	70	5.8
Related unambiguous primes	57	6
Unrelated primes	66	5.9

Table 5.17. Mean frequency and length values in Experiment 8.

The whole experimental list is reported in Appendix. Two hundred sixty-six prime-target pairs were included in the list as fillers. Twenty-six of these pairs were composed by real unambiguous words used as prime and target (W-W). The other filler pairs were made as follows:

- 80 non word prime – word target pairs (NW-W);
- 80 word prime – non word target pairs (W-NW);
- 80 non word prime – non word target pairs (NW-NW)

Thirty-six of W-NW pairs were orthographically related, analogously to experimental condition (e.g., *chiudo*→*chiurevo*, I close→non word).
All the real words used in the filler pairs were unambiguous words, matched with experimental items for their mean length and for their frequency; half of the fillers were nouns and half were verbs.

Experimental session. The whole experiment was arranged in three different sessions, each containing three hundred twenty prime-target pairs. In each session there were all the fifty-four targets, but each target was presented only once in one of the three conditions (either preceded by the related ambiguous prime, or preceded by the related unambiguous prime, or preceded by the unrelated prime). The three different conditions were equally distributed in the three sessions. Each session was divided in five blocks: each block was composed of sixty-four items.
Five randomizations for the order of presentation of the blocks and two randomizations for increasing and decreasing alphabetic order of presentation of the stimuli in each block were created.

Participants. Seventy-five participants, all students of the University of Salerno, and native speakers of Italian, took part into the experiment. They served for a session lasting about twenty minutes. Each participant was submitted to a single experimental session. Each group of three participants constituted one data point in the statistical analyses.

Equipment and *procedure* were the same as in Experiment 7.

5.3.3.2 Results and Discussion

In Table 5.18 mean reaction times, percentage of errors and size of condition effects are shown.

	Contr. condition	Morph. condition	Exp. condition	Morph-contr	Exp-contr
RT	589	571	582	-18	-7
Errors	5.3	3.6	4.5	-1.7	-0.8

Table 5.18. Mean correct LD latencies (in milliseconds), percentage of errors and condition effects

The ANOVA on response latencies revealed a significant condition effect between the morphological and the control condition (ANOVA by participants $F(1,24)=.22$; $p<.001$; ANOVA by item $F(1,102)=4.9$; $p<.01$). Also the ANOVA on error data showed a significant effect (ANOVA by participants $F(1,24)=.12$; $p<.001$; ANOVA by items $F(1,102)=4.5$; $p<.05$).
The ANOVA on response latencies did not show any significant condition effect between the experimental and the control condition (ANOVA by participants $F(1,24)=2.7$; ANOVA by item $F(1,102)=.1$). Also the ANOVA on error data did not reveal any significant effect (ANOVA by participants $F(1,24)=1.9$; ANOVA by items $F(1,102)=.93$).

In Table 5.19 the mean reaction times and percentage of errors of each subset of experimental and control items are shown. Table 5.20 shows the size of condition effects in response latencies and percentage of errors.

	Control condition	Morphological condition	Experimental condition
N>V	587 (4.6)	560 (3.6)	598 (4.6)
V>N	594 (5.9)	579 (3.8)	575 (4.5)
N=V	585 (5.5)	573 (3.3)	575 (4.4)

Table 5.19. Mean correct LD latencies and percentage of errors in each subset of stimuli

	(morph-contr)	(exp-contr)
N>V	- 27 ms (-1%)	+ 11 ms (0%)
V>N	- 15 ms (-2.1%)	- 19 ms (-1.4%)
N=V	- 12 ms (-2.2%)	- 10 ms (-1.1%)

Table 5.20. Condition effects of each subset in response latencies. In parentheses the effects on errors.

Post-hoc analyses based on the ANOVA by participants on response latencies showed a significant difference between the morphological and control condition in N>V ($p<.001$) and V>N ($p<.03$), but not in N=V ($p<.1$). Post-hoc analyses based on the ANOVA by participants on response latencies showed a significant difference between the experimental and control condition in V>N ($p<.01$), but not in N>V ($p<.1$) and N=V ($p<.1$).

In Figure 5.8 mean reaction times of each subset of experimental, morphological and control items are graphically shown; significant differences in post-hoc analyses are highlighted.

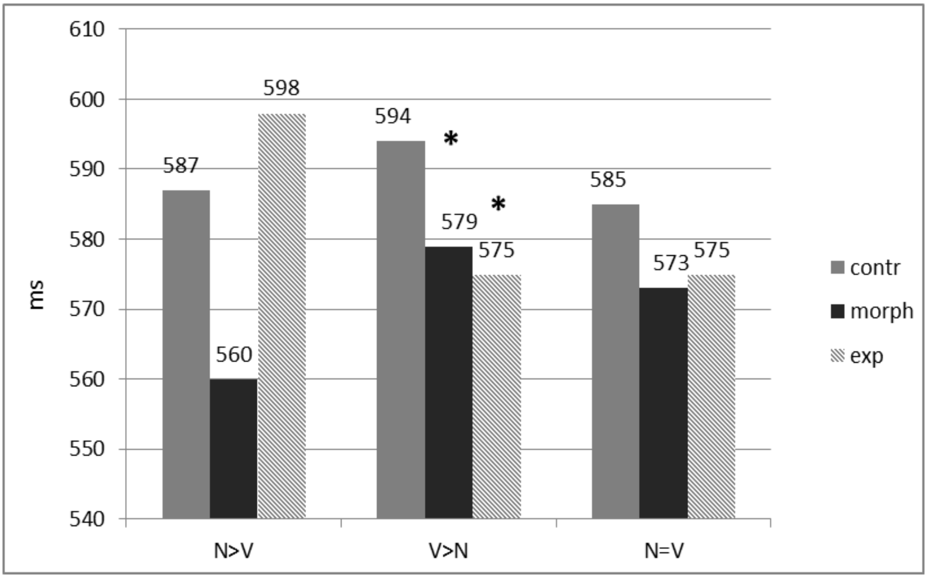

Figure 5.8. Mean reaction times in each subset of items

Post-hoc analyses based on the ANOVA by participants on error data revealed a significant difference between the morphological and control condition in V>N ($p<.05$) and N=V ($p<.009$), but not in N>V ($p<.3$). Post-hoc analyses based on the ANOVA by participants on error data did not reveal any significant difference between the experimental and control condition (N>V: $p<.1$; V>N: $p<.1$; N=V: $p<.2$).

In Figure 5.9 percentages of errors of each subset of experimental, morphological and control items are graphically shown; significant differences in post-hoc analyses are highlighted.

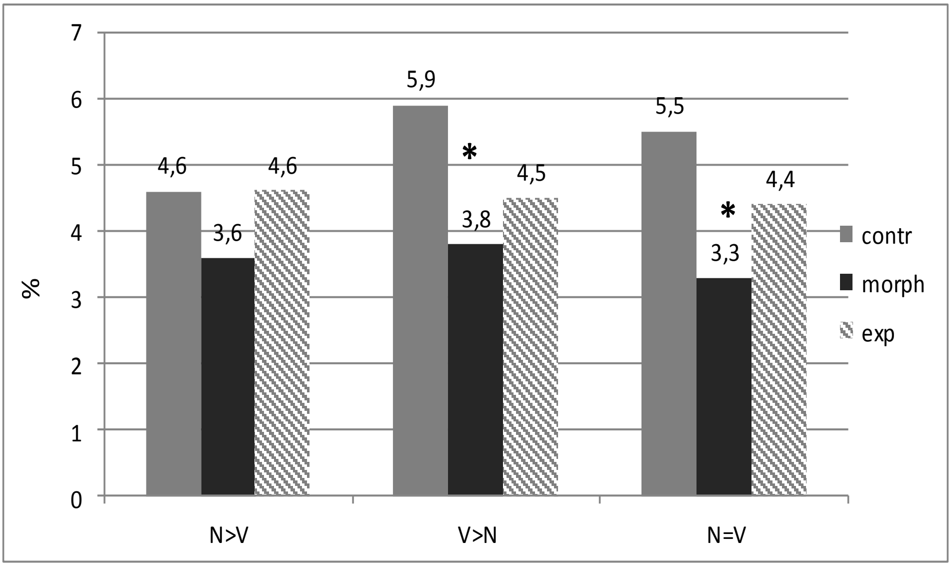

Figure5.9. Percentage of errors in each subset of items

The overall results reveal a significant morphological priming effect only when primes are morphologically related to targets but they are not ambiguous (morphological condition, e.g., *abita→abitata*). In the experimental condition, no morphological facilitation is detected.

Single comparisons reveal a more complex pattern: whereas the condition effect between the morphological and the control condition is reported in any subset of items, processing differences are found in the comparison between the experimental and the control condition, due to the frequency dominance of ambiguous primes. Specifically, the facilitatory effect is found in RT analyses only when targets are preceded by ambiguous related primes with a dominant verbal meaning (V>N forms).

Moreover, in the opposite situation, namely when ambiguous primes are more frequent as nouns (e.g., *abito→abitata*) , an approximately significant inhibitory effect is found. This finding could interpreted as follows: since N>V primes tend to be accessed as nouns, depending both on the frequency dominance of these items and on the general tendency of bare ambiguous words to be assigned to the nominal class (*nominal* *dominance hypothesis*), there is only an orthographic relation between primes and targets. Consequently, the morphological and semantic priming decays: primes and targets of these type become only stem-homographs, namely words which are morphologically unrelated and tend to inhibit each other in the lexical retrieval.

5.3.4 Discussion

The aim of the two experiments reported above was to investigate the lexical processing of ambiguous words by taking into consideration the role of a slightly different type of "contextual" information. Specifically, the question which inspired my experiments was to understand how meaning frequency dominance information interacts with morphological information.

By considering the overall results of Experiments 7 and 8, the answer is that this variable plays a role in how multiple meanings are lexically processed, even in presence of morphological information.

In the two experiments, homonyms could be preceded or followed by unambiguous verbs morphologically related or not to their verbal entry. Depending on the meaning frequency dominance, homonyms could be morphologically related to the unambiguous prime/target word with either their dominant, subordinate or balanced verbal meaning. When the homonyms were used in prime position, a further morphologically related condition was inserted, in order to deepen the role played by the ambiguity status in modulating the morphological priming effect.

The results of the two experiments were different. In Experiment 7, where homonyms were presented as targets, the overall results revealed a significant morphological priming in the related condition. By taking into consideration the single subsets of items, a slight modulation of the morphological priming facilitation was found, depending on the meaning frequency dominance of the ambiguous forms. The prediction of a role played by this variable even in presence of morphological factors was confirmed; however, the most interesting results were found in Experiment 8, where ambiguous forms were presented in prime position.

The ambiguity status blocked the classic morphological priming effect: when targets were primed by category-ambiguous words, there was no facilitation effect with respect to the unrelated condition. The single comparisons between subsets of homonyms revealed that the morphological priming effect was strongly modulated by the meaning frequency dominance of homonyms: only when the prime was more frequent as verb, it facilitated the target recognition.

The same result pattern was not found in Postiglione and Laudanna (submitted), where the morphological priming effect was less affected by the meaning frequency dominance of polysemous past participles.

Even when verbal targets were primed by ambiguous words more frequent as nouns, there was a strong facilitation effect. Differently from homonymous words, however, both entries of polysemous words adopted in their experiments were semantically and morphologically related to the verbal target, independently on the meaning frequency dominance.

As to homonymous words used in my experiments, the nominal entry of homonyms had no semantic or morphological relatedness with the verb target: they shared only the orthographic form, namely they were stem-homographs. When homonyms words were more frequent as nouns, the morphological facilitation effect was abolished by the inhibitory stem-homograph effect: it resulted an absence of morphological priming, and an approximately significant inhibitory effect on N>V forms.

5.4 General discussion

In this part of my research, I was interested in investigating the lexical processing of ambiguous words in presence of both semantic and morphological information biasing towards one of two possible interpretations of these forms. Specifically, I intended to test the hypothesis of different ambiguity effects depending on the meaning frequency dominance and the grammatical class of ambiguous words.

Whereas in the first part of my research (Exp. 1-3) the role played by these variables had been observed in single visual word recognition tasks, now the question which inspired this set of experiments was to evaluate how these factors interact with "contextual" information.

As discussed in the review on lexical resolution studies, many researchers have addressed the issue of how context is used by speakers to disambiguate ambiguous material and at which stage of lexical processing it intervenes. Nowadays, the empirical evidence seems to converge on the idea that both frequency dominance and context cooperate in lexical disambiguating processes. Nevertheless, to my knowledge, no previous study has investigated the interaction between grammatical class and meaning frequency dominance on one hand, and contextual information on the other hand.

Moreover, in all studies which have addressed the issue of the role played by context, ambiguous words were presented within a sentence, which could be either disambiguating or not. As in this work I was more interested in understanding the lexical representation and processing of ambiguous words rather than the ambiguity resolution processes, I did not use sentences, but single words.

In my first two experiments, I obtained multiple subsets of ambiguous words, by manipulating the meaning frequency dominance and the grammatical class of the stimuli. The homonyms were preceded (Exp. 5) or followed (Exp. 6) by single unambiguous words which could be semantically related or not to one of the two possible meanings of the homonyms.

In all subsets, the unambiguous words were always related to the nominal meaning of homonyms. Depending on the meaning frequency dominance of items, they were related to the dominant, subordinate or one of two balanced meanings.

In both the naming experiments based on semantic priming, a strong modulation of semantic facilitation due to the frequency dominance of ambiguous words was reported: the most interesting result was the absence of any effect when the semantic relation between prime and target was mediated by the less frequent meaning of the homonyms. A relevant difference due to grammatical class was reported in Experiment 6 between noun-noun homonyms and noun-verb homonyms: when balanced ambiguous forms were presented as primes, the semantic facilitatory effect was reported only in the case of N=V forms. For these forms, the nominal entry is more likely to be activated and facilitate the semantically related target, even though meanings are balanced.

In the other two experiments, I presented word-pairs which were morphologically related or not. Differently from all previous experiments, I restricted my investigation to noun-verb ambiguous forms, because all the unambiguous forms used either as primes (Exp. 7) or as targets (Exp. 8) were related to the verbal entry of the homonyms. Thus, in this set of experiments only the meaning frequency dominance of the stimuli was manipulated.

Also in these experiments a modulation of morphological priming effects was reported, due to the meaning frequency dominance of ambiguous words. In Experiment 7, a facilitation effect was always found, even it was stronger when primes were related to the dominant meaning of ambiguous targets. By reversing the order of presentation of prime and target, the facilitatory effect was found only in the dominant condition, namely when homonyms more frequent as verbs were presented as targets, preceded by primes morphologically related to the verbal entry.

Generally speaking, the results of this part of my research can be interpreted as an evidence that meaning frequency dominance and grammatical class operate in lexical processing of ambiguous words, even in presence of both semantic and morphological information. My findings corroborate the idea that the processing differences I found reflect different lexical representations among categories of ambiguous items.

Meaning frequency dominance and grammatical class are relevant factors in lexical ambiguity processes and succeed in modulating both semantic and morphological priming. Moreover, the results obtained in these experiments shed light about which information levels are involved in word lexical access. Both semantic and morphological features seem to be crucial in word lexical retrieval processes.

The next step of my research was to investigate the lexical processing of ambiguous words which have two distinct but related meanings, namely polysemous words. Different lexical representations for polysemous words with respect to homonymous words were predicted: namely a common lexical representation where partially overlapped semantic features are stored. The aim of the following two experiments was to evaluate the role played by meaning frequency dominance and grammatical class in the processing of this type of ambiguous forms. In the following chapter, I will report the results of a naming and a lexical decision experiments where the processing of bare polysemous words were compared to unambiguous control words.

5.5. CONCLUDING REMARKS

In this chapter I aimed at deepening the role of meaning frequency and grammatical class effects in lexical processing of ambiguous words, focusing on how these variables interact with contextual information biasing towards one of two possible meanings of homonyms.

Summing up:

- By manipulating grammatical class and meaning frequency dominance of the homonyms a modulation of semantic and morphological priming effects was obtained.
- In two semantic priming naming experiments the most interesting datum is the absence of facilitatory priming when the prime-target semantic relatedness involves the less frequent meaning of the homonyms.
- Processing differences are also reported between homonyms belonging to the same grammatical class and homonyms belonging to different word classes.
- As to two morphological priming lexical decision experiments, a modulation of the facilitatory condition effect is also reported, even though the morphological priming effect seems to be more resistant.
- The meaning frequency effect strongly modulates the condition effect when homonyms are presented in prime position: the facilitation is reported only when the targets are morphologically related to the dominant verbal entry of homonyms.
- A bias to an inhibitory stem-homograph effect is also reported when homonymous primes are noun-dominant: if accessed exclusively as nouns, these forms are only orthographically related to verbal targets.
- The results obtained in this set of experiments seem to confirm the importance of both meaning frequency dominance and grammatical class effects in lexical access of homonymous words.

Open issues:

- How are polysemous words lexically represented and processed?
- Which is the role of the polysemy in word recognition? Does lexical processing of polysemous words differ from words with a single meaning?
- Is it reasonable to predict different lexical representations and, consequently, processing differences between homonymy and polysemy?
- Which role is played by grammatical class and frequency dominance in lexical access of polysemous words?


sigh... you know things are bad when you confuse your lab key with your apartment key...
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CHAPTER 6

A GLANCE AT POLYSEMY: SENSE EFFECTS IN WORD RECOGNITION

6.1 Introduction

The aim of the experiments described in this chapter was to investigate the factors which affect the lexical processing of ambiguous words with two related senses (polysemous words) in single word recognition tasks. By using the same experimental design as in the first two experiments on homonymy, I also aimed at testing the hypothesis of processing differences between homonymous and polysemous words.

In the preceding chapters, the review of previous research on ambiguity advantage effect showed that the semantic relatedness among meanings of ambiguous words was not systematically taken into consideration. Nevertheless, recent works (Beretta, Fiorentino, & Peoppel, 2005; Klepousniotou, 2002; Klepousniotou et al., 2012; Klepousniotou & Baum, 2007; Rodd et al., 2002), compared the lexical processing of homonymous and polysemous words and found significant processing differences, due to the fact that these forms are likely to be differently stored in the mental lexicon. These findings are compatible with the idea that the homonymy/polysemy distinction has cognitive implications.

Homonyms usually arise through a historical accident such that two different word meanings converge on the same phonological/orthographic representation, or where a single form stays for very different meanings. In contrast, the multiple uses of a polysemous word are related to one another and clearly arisa through a process of extension of similar meanings rather than through an arbitrary historical coincidence (Clark & Clark, 1979; Sweetser, 1990). For example, the word *paper* refers to a "substance made out of wood pulp, a blank sheet of that substance, a daily publication, or an article that is printed on that substance" (Klein & Murphy, 2001, p. 1). Rather than being an exception, polysemy can be found in most content words to at least some degree.

The outlines of a theory of homonymic representation are fairly clear. The different meanings of *bank* or *calf* are considered to be different words, so it is generally believed that they are represented by different *lemmas* or lexical units (Levelt, 1989). In lexicology, homonyms are also considered as different words, as indicated by separate dictionary entries (Zgusta, 1971). It is not exactly understood how speakers identify which meaning of a homonym is intended, but there is fairly good agreement that these meanings are lexically separated. In contrast, there is no such agreement for polysemous word. Should the sense of *paper* meaning "substance made from wood pulp" be in the same lexical entry as "sheet of writing material"? Linguists varied their approach to this problem, ranging from predicting that there is a single represented sense that accounts for all the uses of a word (Ruhl, 1989) to suggesting that each distinguishable sense is separately represented. Thus, the questions of how many senses are represented, how they are linked in memory, and how they are coordinated in processing are the critical issues surrounding polysemy.

In an influential paper, Nunberg (1979) argued against the idea that all distinct senses are represented in the lexicon. Instead, he proposed that some pragmatic principles could be used to derive word senses from others. According to this theory, all that is lexically represented would be a "core meaning" of a word; consequently, the different extensions of a polysemous word would be generated online, using pragmatics and plausible reasoning. On this view, different senses would be not pre-stored but rather calculated from contextual features.

A similar account was proposed by Caramazza and Grober (1976), who identified 26 separate but related senses for the word *line*. They suggested that those senses are all related to a core meaning and that "it is precisely the core meaning that is stored in the psychological representation for the meaning of *line*" (p.188). They argued against the notion that each sense is explicitly stored in the mental lexicon. Also Ruhl (1989) argued that there is a single, defining sense for words (even most homonyms), with created or stored distinct senses. Lehrer (1990) agreed with Nunberg that much polysemy can be predicted through general principles of meaning extension, but she also noted that these principles sometimes do not succeed. She argued that the lexicon is simply unpredictable and that speakers must learn which words can be extended in which ways, rather than relying entirely on pragmatic principles. In lexicology, Zgusta (1971) argued that it is usually impossible to find a single basic sense of a word from which the other senses can be derived. Thus, within the linguistic literature there is a variety of views on how explicit the lexicon must be - whether each word sense must be represented or instead is derived from a more basic meaning.

Few psychological studies have addressed this issue. Williams (1992) found that contextually irrelevant senses of polysemous words are active even over long delays in a lexical decision task. He examined the literature on homonyms, which shows that priming effects for the contextually irrelevant meaning of homonymous words are short-lived. Hence, Williams argued that the senses of polysemous words cannot be represented independently, as homonym meanings are (see also Durkin & Manning, 1989). One possibility is that the polysemous senses are connected through a common core.

Additional support for the core concept view of polysemy came from the work of Anderson and Ortony (1975), who argued that understanding is more than finding the correct lexical entry in a semantic associative network. According to their work, both context and world knowledge must be involved in deriving the representations of a polysemous word. Thus, they argued that semantic memory is not rich enough to explain how polysemous words are interpreted. Like Caramazza and Grober (1976), they suggested that the lexical network contains core information, and other information necessary to understand the exact sense of the word is provided by context. Generally, core-meaning theories suggest a view of polysemous senses as being somewhat temporary: meanings can be augmented in a given context, but those extended senses are not permanently stored in the lexicon.

Another view of polysemy representation is one that is much closer to homonym representation. According to this perspective, common senses would have separate entries – like homonyms – although connected to the same *lemma*. Such views can vary considerably, depending on how many senses they claim are represented and on whether one of these senses is picked out as being the core meaning. For example, an important question surrounding this approach is how to decide which senses are distinct and when a sense rises above a mere occasional usage to obtain a full lexically representation. Many linguists seem to converge on the idea that some reasonable number of senses are represented, rather than only a single (core) meaning or every possible sense (e.g., Cruse, 1986; Deane, 1988; Langacker, 1987; Rice, 1992; Tuggy, 1993).

As already mentioned, there is very little experimental evidence to support either the core or the multiple-sense theory or to provide constraints on either view, and what evidence exists is often muddied by the use of homonyms in the polysemous stimuli, and vice versa.

Given the differences between polysemy and homonymy, it is obviously crucial to keep these two phenomena distinct in the investigations. Homonymy is the unpredictable coincidence of two different words having the same name; in contrast, polysemy is the normal, expected presence of related senses in a word. Unfortunately, psychologists have not been very good at separating these two kinds of ambiguity, both in terminology and methodology. In particular, the term *polysemy*, which is used in linguistics to refer to a word having related senses (e.g., Cruse, 1986; Geeraerts, 1993), is often used as a synonym for *ambiguity* (including homonymy) in the psychological literature. For example, Hino and Lupker (1996) titled their article “Effects of Polysemy . .” and then referred to their stimuli as “ambiguous” and “unambiguous.” Furthermore, studies of ambiguity have sometimes combined these two phenomena in their experimental designs by treating homonyms and polysemous words as both "ambiguous."

The main aim of the experiments to be described is to provide data to account for the representation and processing of polysemous words.

By using the same experimental design adopted for homonyms (Exp. 1 & 2), I addressed three main questions:

Do polysemous words differ from unambiguous words in visual word recognition tasks?

Do lexical representation and processing of polysemous words differ from homonymous words?

Is lexical processing of polysemous words affected by the same variables which are predicted to intervene in homonymy processing?

If polysemous words have only a core meaning, specific senses being derived online, then different uses of a word should have shared representations. Conversely, if each sense of a polysemous word is encoded and represented separately, then the representation of one use of the word might not overlap that of a different use of the same word. Obviously, there are also a number of intermediate possibilities, in which a core part of the meaning is shared by most senses, varying in how much information is in the core and how much is in the senses.

In the following experiments, the polysemous material was tested both in lexical decision and in naming tasks. The general prediction was to report results reflecting how polysemous words are lexically represented. As in experiments on homonyms, I tried to verify if the lexical processing of these forms is affected by two variables which have not been taken into account in the previous works on the topic:

- ✓ the grammatical status of these forms, namely, whether there are processing differences between polysemous forms belonging to the same grammatical class (e.g., *cornice*, meaning both *frame* and *context*) and grammatically ambiguous forms between nominal and verbal classes (e.g., *trovata*, which means both *brilliant idea*, nominal sense, and *found,* verbal sense).
- ✓ the meaning frequency dominance, that is whether there are processing differences between balanced polysemous words (two

senses which have equal probabilities of occurrence, e.g., *inviato*, meaning both *correspondent* and to *sent*) and unbalanced polysemous words (having a more frequent sense, e.g., *allarme*, which means both *acoustic alarm* and *panic*).

By manipulating these two factors, I expected to find different polysemy effects depending on how these forms are lexically stored and processed during meaning access.

The meaning collecting procedure was the same used for homonyms: multiple senses of polysemous words were gathered on the basis of both dictionary entries and users knowledge. Differently from homonyms, words with related senses do not necessary have distinct entries in dictionaries: they are often described in a unique entry as a list of possible nuances and context occurrences. Even for this kind of forms, I excluded from my investigation words with more than two senses, in order to avoid possible meaning/sense number effects; secondly, I counted the relative frequencies of multiple meanings in written Italian corpora, in order to distinguish balanced and unbalanced polysemous words; finally, two off-line rating tasks (meaning generation task and semantic association task) were carried out to test the actual speakers knowledge of all multiple senses. Although my results do not pretend to be able to narrow the field down to a single explanation, it is important to perform empirical work that elucidates the representation of polysemy, because of its implications for our understanding of lexical processing and representation. Gerrig (1986) pointed out that considerable psycholinguistic research addresses how meaning is used in lexical access and discourse comprehension; yet there is little agreement on exactly what semantic information is included in lexical representations. Thus, specifying the representation of polysemous words is a necessary part of explaining how meaning is represented and involved in production and comprehension.

6.2 Experiment 9 – Naming

6.2.1 Method

Stimuli. Ninety polysemous words, having two distinct but related senses, were selected and split in five subsets:

- 18 were more frequent as nouns (N>V e.g., *scherzo*, joke/I joke);
- 18 were more frequent as verbs (V>N e.g., *trovata*, found/idea);
- 18 had two balanced nominal meanings, (N=N e.g., *cornice,* frame/context);
- 18 had two unbalanced nominal meanings (N>N e.g., *allarme*, acoustic alarm/panic);
- 18 had two balanced nominal/verbal meanings (N=V e.g., *inviato* , journalist abroad/sent).

Like the experiments on homonyms, the threshold value to distinguish between balanced and unbalanced forms was established on the basis of the ratio between the relative frequencies: all the polysemous words which did not exceed the ratio value of 2.5 (e.g., Sense 1 frequency value 10 / Sense 2 frequency value 4 = 2.5 ratio) were considered balanced; starting from the ratio value of three up, they were considered unbalanced.

All frequencies were calculated on the basis of a corpus of almost 4.000.000 occurrences (CoLFIS, Bertinetto et al., 2005). As far as ambiguous forms between noun and verb are concerned, the procedure to determine the two relative frequency values was simple, because the corpus is able to disambiguate automatically between distinct lemmas belonging to different grammatical classes. The same procedure was not possible for ambiguous forms belonging to the same grammatical class: in this case, a manual consultation of corpora was required in order to disambiguate the context usage and calculate how many times an ambiguous word occurs either in a sense or in another one.

The critical items were submitted to a group of participants in two off-line ratings, the same used for homonymous material. Eighty Italian mother-tongue undergraduates from University of Salerno participated in the meaning generation task. One hundred-eighty Italian words were selected in the questionnaire: half of the words were potentially ambiguous; the other half were unambiguous (both nouns and verbs). The items were assigned to two questionnaires of ninety words each. Without any time limit, participants were asked to say as many senses as they could think of for each word. As I had previously excluded those ambiguous words with more than two senses, the lists contained either words referring only to one or two senses. The questionnaire results produced a database of word senses that was later used to select experimental materials for the naming task. I used only the polysemous words for which at least the 80% of subjects had listed both the senses.

The second off-line rating was a semantic association task. The aim of this test was to specify which sense of ambiguous words was perceived by users and in which order of frequency. As in the previous task, ninety words were potentially ambiguous and the other half unambiguous (both nouns and verbs). For each word, I selected the associated word which was the most reported by participants in the meaning generation task to create the word pairs (e.g. 'scarpa', meaning 'shoe', followed by 'piede', meaning 'foot'). For ambiguous words, I used both the most frequent words related to the two distinct meanings (e.g., the word 'allarme', meaning both 'acoustic alarm' and 'panic', followed either by the word 'rumore', meaning 'noise', and 'ansia', meaning 'anxiety'). The two-hundred and seventy word pairs obtained were assigned to three questionnaires of ninenty words each. Without a time limit, sixty participants were asked to rate how the second word of the pair was semantically associated to the first word on a Likert 1-7 scale. The results produced a database of association values that was later used to select experimental materials for the naming task. I used only the ambiguous words for which at least the value 4 was assigned to both their senses.

Each subset of critical stimuli was compared to a subset of unambiguous words (*baseline*), belonging to the same grammatical class of the more frequent meaning of ambiguous words. Specifically, the experimental N>V, N=N and N>N forms were matched with unambiguous nouns, while the V>N forms were matched with unambiguous verbs. The N=V forms – where there is no dominant grammatical class - were compared both to a subset

of unambiguous nouns and a subset of unambiguous verbs. From now on, I will call these forms, respectively, N=V when they are matched to noun controls and V=N when they are matched to verb controls.
Each subset of experimental items was matched with its control subset for their mean frequency (intended as sum of relative frequencies in the case of ambiguous forms).
In Table 6.1 the mean frequency values of the data set are shown.

	Frequency of ambiguous words	Frequency of noun controls	Frequency of verb controls
N>V	131	133	
V>N	103		102
N=N	62	63	
N>N	87	90	
N=V	74	75	
V=N	74		73

Table 6.5. Mean frequency values in Experiment 9.

Experimental stimuli were also matched with control items for their mean length (in number of letters, syllables and phonemes). In Table 6.2 mean length of the data set is reported.

	Letters	Syllables	Phonemes
Exp.	6.7	2.8	6.3
Contr.	6.7	2.9	6.3

Table 6.6. Mean length in Experiment 9.

I submitted the experimental items to speakers in two off-line Likert scale ratings from 1 to 7, in order to match them for familiarity and imageability.

Forty Italian mother-tongue undergraduates from University of Salerno participated in the two off-line tests. Mean familiarity and imageability of the data set are reported in Table 6.3.

	Familiarity	Imageability
Exp.	4.8	4.4
Contr.	4.7	4.5

Table 6.3. Mean familiarity and imageability in Experiment 9.

In order to avoid processing differences in naming, experimental and control stimuli were matched also for their first syllable. Finally, each subset was matched for the number of double consonant words, proparoxytone words, consonant clusters and irregular phonemes (e.g. in Italian, *c, g, gn, gl*).
In Table 6.4 the mean values referring to these orthographic-phonological parameters are reported.

	Double Consonants	Proparoxytone words	Consonant clusters	Irregular phonemes
Exp.	3.8	2	12.5	9.4
Contr.	4.1	1.8	13	9.2

Table 6.4. Mean values of the orthographic-phonological parameters in Experiment 9.

The whole experimental list is reported in Appendix. One hundred fifty-two items were included in the list as fillers. All the filler words were real unambiguous words, matched with experimental targets for their mean length in number of letters and for their frequency. Those words, together with the experimental ones, displayed a grammatical class distribution of written Italian (CoLFIS, Bertinetto et al., 2005). Specifically, fifty-seven were verbs and ninety-five were nouns.

Experimental session. The whole experiment was arranged in a single session, containing three hundred fifty items. The whole session was divided in five blocks: each block was composed of seventy items. Five randomizations for the order of presentation of the blocks and two randomizations for increasing and decreasing alphabetic order of presentation of the stimuli in each block were created.

Participants. Thirty-four participants, all students of the University of Salerno, and native speakers of Italian, took part into the experiment. They served for a session lasting about thirty minutes. Each participant was submitted to the whole experimental session and constituted one data point in the statistical analyses.

Equipment. Microphone and sound recorder, connected to an IBM PC running the E-Prime software (Version 1.1).

Procedure. A naming task was used as experimental paradigm (as in Experiment 1). The experiment was preceded by a practice session. Participants were asked to read aloud the words presented on the screen as fast and accurate as possible. Reaction times and errors constituted the dependent variables. The reaction times were measured from item onset to response of subjects, and the lack of a response was scored as an error. As the microphone connected to the computer measured only the reaction times, all the hesitations and reading errors were recorded and manually reported for the statistical analysis.

6.2.2 Results and Discussion

In Table 6.5 mean reaction times, percentage of errors and size of condition effects are shown.

	Control condition	Experimental condition	Condition effect
Reaction times	503	496	-7
Errors	3.2	3.3	+0.1

Table 6.5. Mean correct naming latencies (in milliseconds), percentage of errors and condition effects

The ANOVA on response latencies revealed a significant result only in the analyses by participants (F $(1,33)=9.6$; $p<.05$; ANOVA by item F $(1,18)=2.54$).
The ANOVA on error data did not reveal any significant condition effect (ANOVA by participants F $(1,33)=2.07$; ANOVA by item F $(1,18)=.06$).
In Table 6.6 the mean reaction times and percentage of errors of each subset of experimental and control items are shown. Table 6.7 shows the size of condition effects in response latencies and percentage of errors.

	Control condition	Experimental condition
N>V	498 (3.6)	497 (1.9)
V>N	500 (2.3)	485 (2.8)
N=N	511 (3.7)	499 (3.3)
N>N	498 (5.6)	487 (3.3)
N=V	496 (1.7)	513 (4.1)
V=N	516 (2.2)	513 (4.1)

Table 6.6. Mean correct naming latencies and percentage of errors in each subset of stimuli

N>V	- 1 ms (-1.7%)
V>N	- 15 ms (+0.5%)
N=N	- 12 ms (-0.4%)
N>N	- 11 ms (-2.3%)
N=V	+ 17 ms (+2.4%)
V=N	- 3 ms (+1.9%)

Table 6.7. Condition effects of each subset in response latencies. In parentheses the effects on errors.

Post-hoc analyses based on the ANOVA by participants on response latencies showed a significant difference between the experimental and control condition in V>N ($p<.05$), N=N ($p<.01$), N>N ($p<.01$), N=V ($p<.001$), but not in N>V ($p<.6$) V=N ($p<.9$).

In Figure 6.1 mean reaction times of each subset of experimental and control items are graphically shown; significant differences in post-hoc analyses are highlighted.

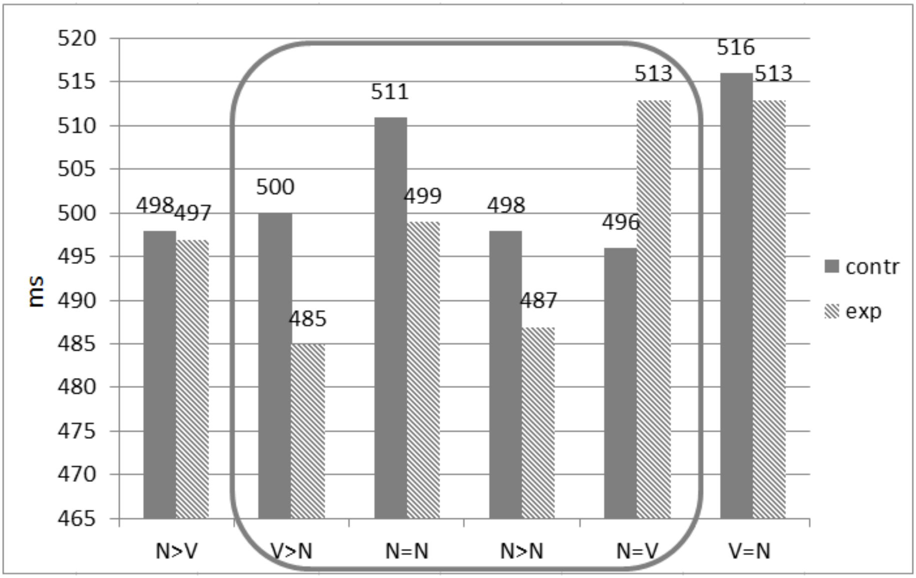


Figure 6.4. Mean reaction times in each subset of items

Post-hoc analyses based on the ANOVA by participants on error data revealed a significant difference between the experimental and control condition in N>N (p<.01), N=V (p<.01), V=N (p<.05), but not in N>V (p<.08), V>N (p<.6), N=N (p<.1).
In Figure 6.2 percentages of errors of each subset of experimental and control items are graphically shown; significant differences in post-hoc analyses are highlighted.

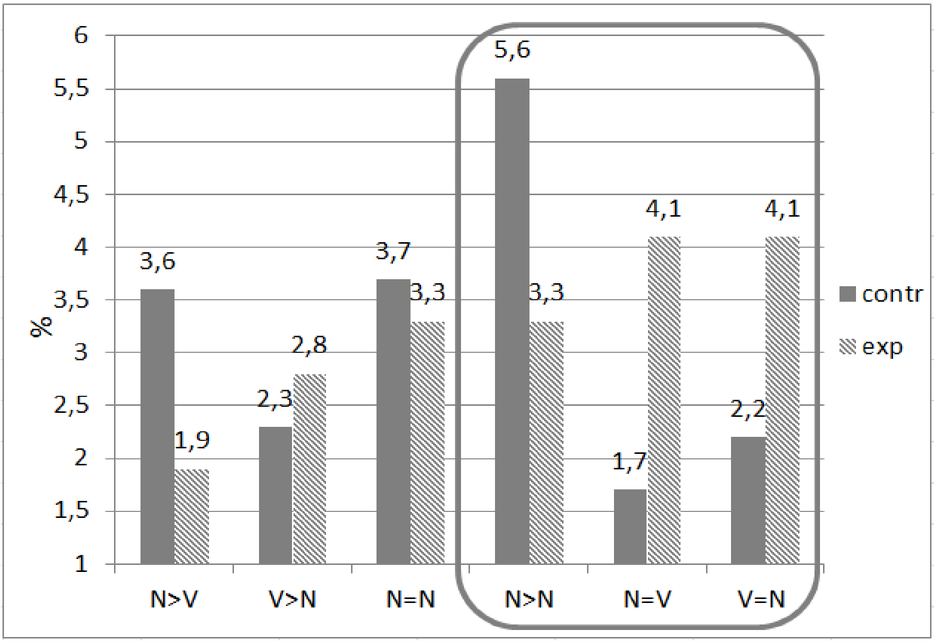


Figure 6.5. Percentage of errors in each subset of items

The overall results of Experiment 9 show an ambiguity advantage, even though the effect is significant only in the RT analyses by participants. Single comparisons reveal a complex pattern of results in speed of naming: for the majority of subsets of polysemous words a significant facilitation is found; in contrast, a significant ambiguity disadvantage is found on N=V forms.
These results seem to confirm the idea of processing differences between polysemous words and unambiguous words: in this experiment a general sense advantage emerges in speed of naming.

Secondly, the findings suggest that polysemous and homonymous words differ from each other in lexical representation: whereas in Experiment 1 and 2 homonymous words showed a substantial absence of processing differences respect to unambiguous words, in this experiment the majority of polysemous words investigated are recognized faster than control words.
Finally, single comparisons between each subset of polysemous stimuli reveal that both grammatical category and meaning frequency dominance play a crucial role in determining different polysemy effects in visual word recognition.
Indeed, polysemy inhibits processing when it involves the syntactic level (different parts of speech) and when sense frequencies are balanced, as with balanced noun-verb homonymous words. On the contrary, polysemy facilitates processing in the majority of the other subsets of ambiguous words. Starting from my first results, an open issue concerns what happens when we compare polysemous words and unambiguous words in a visual lexical decision task and if we can predict similar result patterns depending on grammatical status and meaning frequency dominance.

6.3 Experiment 10 – Lexical Decision

6.3.1 Method

Stimuli. The experimental and control items were the same used in Experiment 9. Five hundred two items were included in the list as fillers. One hundred fifty-two were the same real unambiguous words used in Experiment 9. The list included three hundred fifty items as pseudowords. These fillers were matched with the experimental words for length, calculated in number of letters, and they were obtained by changing one letter of existing low or medium frequency words, for 1/3 in their initial part, 1/3 in their central part and 1/3 in their final part. The whole list was composed of three hundred fifty words and three hundred fifty pseudowords.

Experimental session. The whole experiment was arranged in two different sessions, containing three hundred fifty items. In each session there were presented all fillers and half part of experimental and control stimuli. The whole session was divided in five blocks: each block was composed of seventy items. Five randomizations for the order of presentation of the blocks and two randomizations for increasing and decreasing alphabetic order of presentation of the stimuli in each block were created.

Participants. Forty participants, all students of the University of Salerno and native speakers of Italian, took part into the experiment. They served for a session lasting about thirty minutes. Each participant was submitted to a single experimental session. Each pair of two participants constituted one data point in the statistical analyses.

Equipment. Response box, connected to an IBM PC running the E-Prime software (Version 1.1).

Procedure. A visual lexical decision task was used as experimental paradigm (as in Experiment 2). The experiment was preceded by a practice session. Participants were asked to make a decision in a fast and accurate way.
The reaction times and the errors constituted the dependent variables. The reaction times of right responses were measured from item onset to subject response, while the lack of a response was scored as an error, as the wrong responses.

6.3.2 Results and Discussion

In Table 6.8 mean reaction times, percentage of errors and size of condition effects are shown.

	Control condition	Experimental condition	Condition effect
Reaction times	557	547	-10
Errors	4.6	3.8	-0.8

Table 6.8. Mean correct LD latencies (in milliseconds), percentage of errors and condition effects

The ANOVA on response latencies revealed a main condition effect only in the analysis by participants ($F(1,39)=21.8$; $p<.001$; ANOVA by item $F(1,18)=3.06$).
Also, the ANOVA on error data revealed a main condition effect only in the analysis by participants ($F(1,39)=8.72$; $p<.005$; ANOVA by item $F(1,18)=2.23$).
In Table 6.9 the mean reaction times and percentage of errors of each subset of experimental and control items are shown. Table 6.10 shows the size of condition effects in response latencies and percentage of errors.

	Control condition	Experimental condition
N>V	556 (5)	545 (3.3)
V>N	560 (8.1)	542 (3)
N=N	567 (5)	548 (3.5)
N>N	550 (3.5)	522 (2.8)
N=V	527 (2.9)	562 (5)
V=N	581 (3)	562 (5)

Table 6.9. Mean correct LD latencies and percentage of errors in each subset of stimuli

N>V	- 11 ms (-1.7%)
V>N	- 18 ms (-5.1%)
N=N	- 19 ms (-1.5%)
N>N	- 28 ms (-0.7%)
N=V	+ 35 ms (+2.1%)
V=N	- 19 ms (+2%)

Table 6.10. Condition effects of each subset in response latencies. In parentheses the effects on errors.

Post-hoc analyses based on the ANOVA by participants on response latencies showed a significant difference between the experimental and control condition in V>N (p<.005), N=N (p<.04), N>N (p<.001), N=V (p<.004), V=N (p<. 008), but not in N>V (p<.4).

In Figure 6.3 mean reaction times of each subset of experimental and control items are graphically shown; significant differences in post-hoc analyses are highlighted.

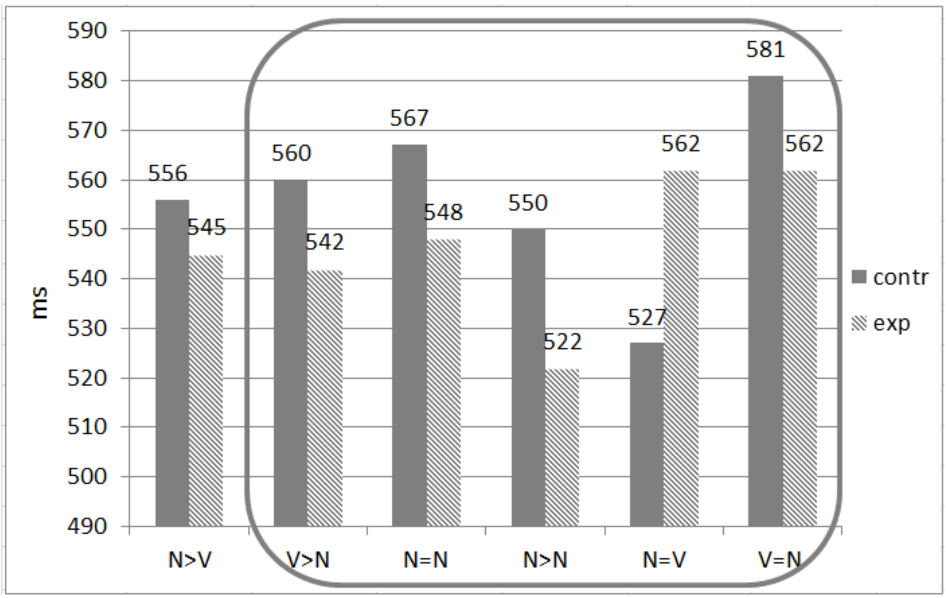


Figure 6.6. Mean reaction times in each subset of items

Post-hoc analyses based on the ANOVA by participants on error data showed a significant difference between the experimental and control condition in V>N (p<.007), N=V (p<.05), but not in N>V (p<.3), N=N (p<.4), N>N (p<.3), V=N (p<.1).

In Figure 6.4 percentages of errors of each subset of experimental and control items are graphically shown; significant differences in post-hoc analyses are highlighted.

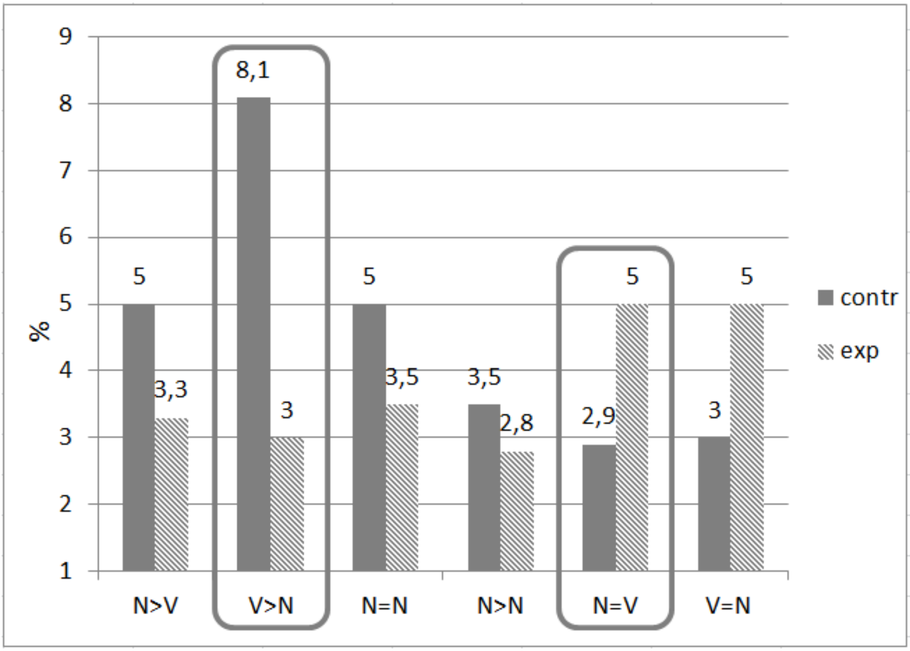


Figure 6.7. Percentage of errors in each subset of items

The overall results of the Experiment 10 show an ambiguity advantage: polysemous words are significantly recognized faster and better than unambiguous words. Single comparisons reveal a more complex pattern of results depending on the meaning frequency dominance and grammatical class of polysemous words: as in the previous experiment, a significant ambiguity disadvantage is found on N=V forms; for the majority of the other subsets of polysemous words a significant facilitation effect is reported.

These result patterns seem to confirm again that polysemous words differ from both unambiguous and homonymous words in lexical processing, as they exhibit a substantial sense advantage effect. As to grammatical category and meaning frequency dominance, they are demonstrated to play a crucial role also in determining different polysemy effects in visual word recognition.

6.4 General discussion

In this part of the research, I aimed at investigating the lexical processing of polysemous words, in order to shed light on how multiple related senses are stored in the mental lexicon. Although polysemy is a much more frequent phenomenon in language, most psycholinguistic studies to date have focused mainly on homonymy comprehension processes.

I started from the question of whether polysemous words differ from unambiguous words in visual word recognition tasks and whether variables such as grammatical class and meaning frequency dominance affect the polysemy processing, as reported in experiments on homonymy. By using the same experimental design adopted for homonymous words (Exp. 1 & 2), I was able to test also the hypothesis of processing differences between homonymous and polysemous words. Specifically, the idea was that previous research on the topic had obtained controversial patterns of results because most studies did not distinguish among different types of lexical ambiguity, treating lexical ambiguity as an all-or-nothing phenomenon. In the linguistic literature, however, the concept of ambiguity is more articulated. In particular, a clear distinction is made between homonymous words, that have multiple unrelated meanings, and polysemous words, with multiple senses based on the same original meaning. Understanding whether this linguistic distinction is psychologically real appears crucial. A number of recent studies, focusing on the semantics of ambiguous words, provided evidence for differences in processing between homonymy and polysemy (Beretta, Fiorentino, &

Peoppel, 2005; Klepousniotou, 2002; Klepousniotou et al., 2012; Klepousniotou & Baum, 2007; Rodd et al., 2002).

By considering the results of Experiments 9 and 10, I may answer that representation and processing of polysemous words differ both from unambiguous and homonymous words. Anyway, also polysemy cannot be observed as a homogeneous phenomenon, because many variables seem to play a crucial role in how multiple senses are lexically represented and processed.

In the experiments reported, the investigation was confined to words with two related meanings and naming and lexical decision tasks were carried out in order to compare two tasks involving different information levels and strategies. I also took into consideration the sense collection procedure, which has been demonstrated to be crucial in determining the nature of the ambiguous materials. Finally, I manipulated the grammatical class and the meaning frequency dominance of polysemous words in order to evaluate the impact of these variables in determining polysemy effects.

Significant processing differences between polysemous and unambiguous words were found: polysemous words were recognized faster and better than control words with a single meaning. The same facilitation was not found on homonymous words, which did not show significant processing differences with respect to unambiguous forms. The experimental design obtained by manipulating grammatical class and meaning frequency dominance allowed me to observe a more complex pattern of results. Specifically, an ambiguity disadvantage effect was reported on N=V polysemous words in both naming and lexical decision task. The same effect had been obtained on the same experimental category of homonymous words. On the majority of the other subsets of polysemous forms a facilitatory effect was reported. In contrast, homonymous forms showed an advantage only on N>N forms.

Thus, words with multiple senses seem to be recognized easier than unambiguous words. Even when any significant effect is reported on some subsets of polysemous words, what emerges is a bias towards the facilitatory effect. Only when the ambiguity involves the grammatical level and senses are frequency-equal (N=V), a polysemy disadvantage effect is reported. Similarly to homonymy processing, both grammatical class and meaning frequency dominance are confirmed to play a crucial role in representation and processing of polysemous forms.

Starting from the results of these experiments, an open issue concerns how grammatical class and meaning frequency dominance effects could be explained and at which stage of lexical processing of polysemous words they could be situated. The idea is that the processing differences I found should reflect different lexical representations among categories of items.

As predicted for homonyms, we can imagine a representation level where morpho-syntactic information about words - such as the word class information - is stored. At this stage, we can situate the ambiguity disadvantage effect depending on the grammatical class: for syntactically ambiguous forms, we can predict two distinct representations, one corresponding to the nominal function and one corresponding to the verbal function. The same representation pattern cannot be supposed for ambiguous forms belonging to the same grammatical class, which share the representation at this level. The competition process between multiple morpho-syntactic representations is supposed to be stronger when two alternative meanings are frequency-equal (N=V). At this processing phase, homonymous and polysemous words are supposed to have similar representations and, indeed, they exhibit the same patterns of results.

After that, semantic information requires to be activated. Differently from unambiguous words, all the polysemous items at this level are supposed to have more than one representation, each corresponding to a specific sense. Since multiple senses of polysemous words are distinct but semantically related, the corresponding representations at the semantic level are partially overlapping.

When speakers encounter a polysemous word in isolation, all the semantic representations of that word are activated, because they are connected with each other. An activation spreading will render more available the output representation and, thus, facilitate the retrieval process. Differently from homonymous words, multiple semantic representations corresponding to different senses of polysemous words are not supposed to compete: they share a common meaning and reciprocally cooperate in word access.

A graphical representation of lexical access of polysemous words is displayed in Figure 6.5.

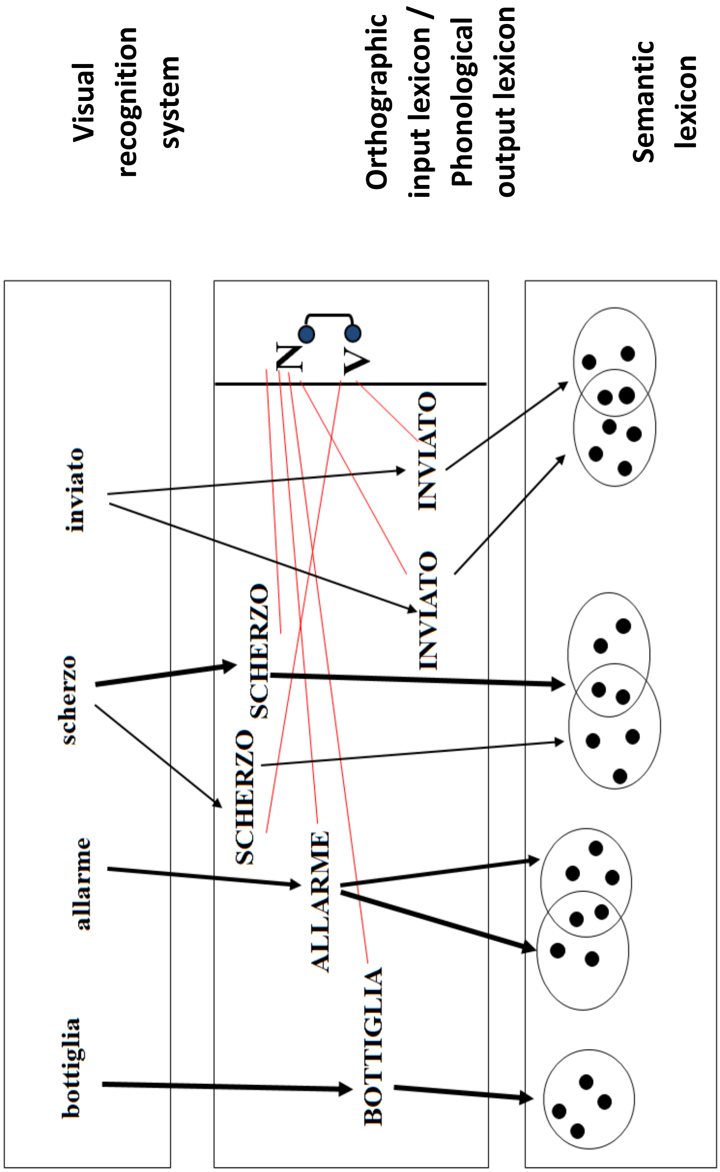


Figure 6.5. Lexical processing of polysemous words

In conclusion, the results obtained in this subset of experiments on polysemous words seem to confirm that the ambiguity status of words plays a crucial role in word recognition. These data seem to provide empirical evidence for the hypothesis of a psychological reality of the homonymy/polysemy distinction.

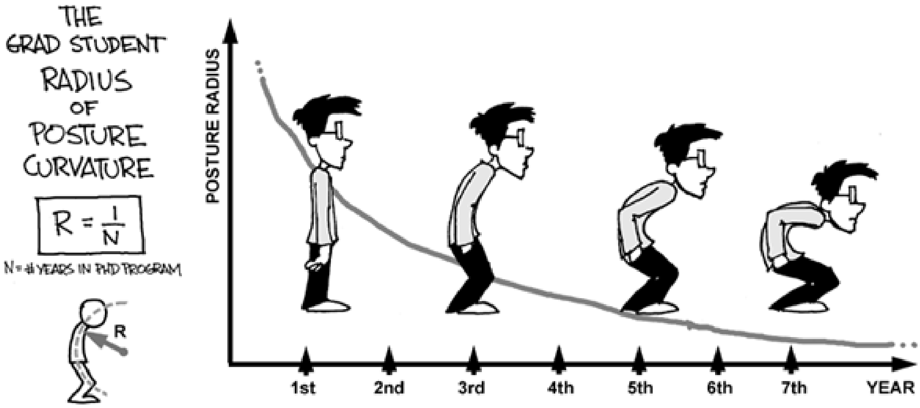
Furthermore, these experiments confirm how lexical ambiguity is an extremely wide phenomenon, and how many variables seem to deeply affect the lexical representations and processing mechanisms of these words.

6.5 CONCLUDING REMARKS

In this chapter I aimed at investigating which factors affect the lexical processing of ambiguous words with two related senses – namely, polysemous words - in single word recognition tasks. Specifically, I tested whether the lexical processing of polysemous words differs both from unambiguous words and homonymous words, in virtue of the idea that multiple senses of these words should affect how they are lexically represented in the mental lexicon.

Summing up:

- The overall results show a significant polysemy advantage effect in visual word recognition tasks.
- Nevertheless, single comparisons among subsets of ambiguous words reveal a more complex pattern of results. Specifically, polysemy inhibits processing when it involves the syntactic level (different parts of speech) and when sense frequencies are balanced. On the contrary, polysemy facilitates processing in the majority of the other subsets of polysemous items.
- The data obtained seem to confirm the idea that the homonymy/polysemy distinction is not merely linguistic, but also involves different lexical representation ways and processing mechanisms.
- The processing differences among categories of polysemous items confirm that many variables seem to play a crucial role in ambiguity effects.


THE
GRAD STUDENT
RADIUS
OF
POSTURE
CURVATURE
R = 1/N
N = # YEARS IN PHD PROGRAM
R
POSTURE RADIUS
1st
2nd
3rd
4th
5th
6th
7th
YEAR

CHAPTER 7

SIMULATING HOMONYMY PROCESSING: A NEURAL NETWORK MODEL

7.1 Introduction

While psycholinguistic theories have traditionally been stated only informally, the development of computational models is increasingly recognized as essential. Specifically, computational models imply the explicit formalization of theories, and also enable prediction of behaviour. Implemented models are especially important not only because human language processing is highly complex, involving interaction of diverse linguistic and non-linguistic constraints, but also because it is inherently a dynamic process.

Models are necessary and useful simplifications of the real world, which enhance our understanding by revealing the abstract principles underlying its complexity. Ideally, models abstract away from those aspects of reality that are circumstantial and irrelevant, while highlighting other aspects that are fundamental in explaining what is under investigation. The simplifying assumptions and abstractions can be taken at various levels. It must be decided which aspects of reality should be represented in terms of the model's architecture, which as representational units or their connections, which as steps in the computational process, which as variables or parameters, and which should simply be left out.

Given adequate input and suitable parameter settings, computer models perform computations, whose outcomes correspond to predictions in accordance with the underlying theory. For example, presenting a language comprehension model with a word or sentence may result in the identification of that word or the interpretation of that sentence. Furthermore, models can also predict error rates and response latencies in specific experimental paradigms.

The model thus *simulates* part of the real world, i.e. the model's behaviour is intended to be similar to the one observed in real-life and in experimental conditions. A comparison of simulation results and experimental data can be expected to lead to a revision or further refinement of theoretical insights. This, in turn, leads to further adaptations in the model and perhaps to more experiments, etc. The classical empirical cycle is graphically represented in Figure 7.1.

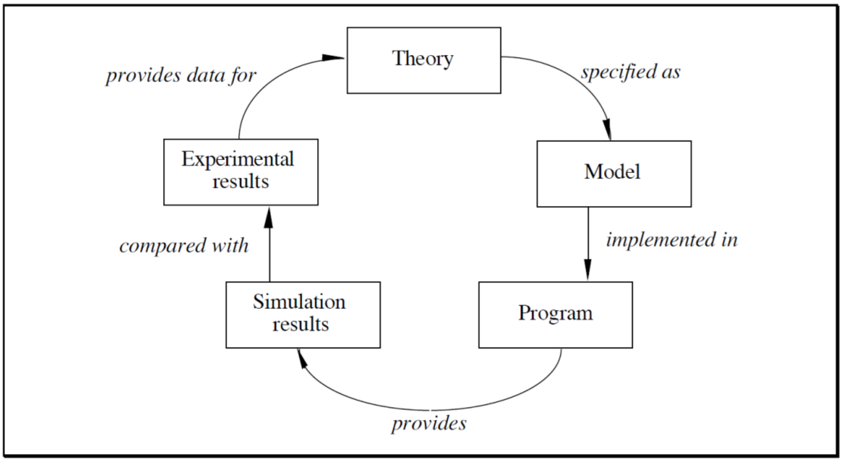


Figura 7.2. Models vs. experiments cycle

Implementing a model on a computer has practical advantages over only formally specifying a computational model. The automaticity, speed, and precision of computers make it possible to run fast and accurate simulations with the implemented model. In the most general sense, a psycholinguistic computer model is designed to reach an outcome similar to that of human language processing. Due to the increasing complexity of scientific theories, simulation is linked with several advantages and important uses in many fields, including psycholinguistics.

Firstly, without computer simulation it is practically impossible to check whether the model is complete and the different parts of the model are internally consistent (in the sense that they do not produce contradictions).

Secondly, predictions made on the basis of a verbal theory for different experimental conditions may be fine-tuned by the computer model to the actually used stimulus material. As has been observed by Cutler (1981), it is becoming more and more difficult to run experiments using stimuli that have been controlled for the increasing number of characteristics that are considered relevant. In the domain of word recognition, relevant factors include word frequency, bigram frequency, number of neighbours, frequency of the neighbours, familiarity, concreteness, etc. However, given the large number of relevant factors, the experimenter must often use less stringent criteria on stimulus matching than he/she would have liked to, simply because the optimal word material does not exist in the language. In this case, computer simulation can be applied as a tool to evaluate the effects of variability in the material that is uncontrolled for or unavoidable.

Finally, even manipulations which cannot be performed in a direct way on human subjects are amenable to simulation. For example, one may simulate successive degrees of lesions to a computer model to invoke effects of aphasia (e.g., Seidenberg, & McClelland, 1989; Haarmann & Kolk, 1991). Although obvious ethical considerations make the replication of such manipulations in an experimental way impossible, simulation results can nevertheless be compared to observable facts in the real world.

In the following, I will report a little review of some most important computational approaches in the domain of visual word recognition and ambiguity resolution processes.

Visual word recognition: a review of the main computational models. The most influential computational models in Psycholinguistics have been those focused on visual word recognition. In fact, there are currently no major psycholinguistic theories of word recognition that do not take the form of a computational model. Competing theories are routinely tested by running the corresponding computational models to determine how well the behaviour of models fits human data. At some level, there is significant theoretical convergence. All of the models of lexical processing are activation-based: lexical access is modelled as a dynamic process of modulating of activation patterns that encode information associated with specific lexical (or morphological) items. However, the models differ dramatically along many important architectural dimensions, such as the degree of top-down feedback and the nature of the computational principles determining the dynamic activation patterns. Current prominent models of visual word recognition take the form of computational models. One of the most influential of these models, the connectionist model of Seidenberg and McClelland (1989) (henceforth SM89), is a descendent of the McClelland and Rumelhart (1981) interactive activation model of word perception, which used localist word, letter, and feature units with hand-coded connections. SM89 builds on this earlier model but adopts distributed representations of both orthographic and phonological information. The model is a feedforward network with one hidden layer interposed between orthographic and phonological units. The connections between units were trained by backpropagation on a simulated word naming task. The model accounts for several phenomena in word-naming, including differences among regular and exception words and differences in word-naming and lexical decision. Since the model exhibits a gradual learning curve, it was also used to simulate the behaviour of children acquiring word recognition skills. One of the major debates in theories of word naming is whether or not there is a single processing route from print to speech, or dual processing routes (lexical and non-lexical). The SM89 model is a clear example of a single-route architecture, and has come under sharp criticism from proponents of dual-route architectures. For example, Coltheart et al. (1993) noted that the SM89 model actually performs more poorly on nonwords than humans do. Dual-route architectures are well-suited to handing nonwords because the non-lexical route implements a general rule-based system that converts letter strings to strings of phonemes. Coltheart et al. also criticised the SM89 model for its inability to account for the dissociations, like in pure developmental surface dyslexia: normal nonword reading accuracy accompanied by gross impairments in reading exception words. Coltheart et al. offered a modular dual-route computational model, the Dual-Route Cascaded Model, which incorporated a learning algorithm for inducing the general string pairs used by SM89. Although Coltheart et al. did not commit to the details of the lexical route, they suggested that something like the original McClelland and Rumelhart (1981) model may be an appropriate realisation of that part of the word naming system. The debate surrounding dual-route and single-route architectures continues, with data from various forms of dyslexia playing an increasingly important role. The dual-route models have evolved to include explicit accounts of both reading aloud and lexical decision (Coltheart et al., 2001), and the connectionist models have evolved away from feed-forward networks toward recurrent attractor networks that are presumed to better handle generalisation (Plaut, McClelland, Seidenberg, & Patterson, 1996).

Modelling the lexical ambiguity resolution. One of the key lessons learned from 40 years of attempting to program computers to process natural language is that massive local ambiguity is pervasive at all levels of linguistic representation. This is clearly evident in lexical processing: words are often associated with multiple syntactic and semantic senses, some mutually, some only partially inconsistent. Many of the theoretical issues in word recognition are important in ambiguity resolution as well, in particular, the degree of autonomy or interaction present in initial lexical access. Different positions on this issue distinguish the major theories of ambiguity resolution (see Chapter 2 for a review of theories): *selective access models*, most closely associated with interactive theories, assume that contextual information provides direct top-down influence on initial sense activation; *ordered access models* assume that different senses are accessed for their frequency of use; *exhaustive access* models, most closely associated with modular theories, assume that all senses are autonomously and exhaustively accessed in parallel; *hybrid* models assume combined effects of context and frequency. Major theories of lexical ambiguity resolution are not strongly identified with specific implemented computational models. However, there have been attempts to build detailed comprehensive computational models. One of the most successful is Kawomoto's (1993) recurrent connectionist model of ambiguity resolution. In this model, each lexical entry is represented by a pattern of activity over a 216-bit vector divided into separate subvectors representing word spelling, pronunciation, part of speech, and meaning. The network is trained by a simple error-correction algorithm, presenting it with the lexical patterns to be learned. The result is that these patterns become attractors in the 216-dimensional representational space. The network is tested by confronting it with part of a lexical entry (e.g., its spelling pattern) and noting how long various parts of the network take to settle into a coherent pattern corresponding to a particular lexical entry. Kawomoto used these settling times to predict reading times, lexical decision times, and semantic access times. The model accounts for a wide range of phenomena, including frequency effects on processing of unambiguous and ambiguous words, context interactions with frequency, and the effect of task on the relative difficulty of processing ambiguous vs. unambiguous words.

In this chapter I will report the results of a simulation carried out by means of a simple neural network model. The general aim of the computational model was to formally explicit the theoretical assumptions of the experimental data reported in Chapter 4 about the lexical processing of ambiguous words. Specifically, in my first two experiments presented in this thesis I found different ambiguity effects in recognizing homonymous words depending both on meaning frequency dominance and grammatical class of these forms. In order to interpret these findings I provided a theoretical model about how these variables are supposed to affect the lexical processing of homonyms and at which stage of lexical access they could be situated (see paragraph 4.2.4 for a wide description of the model). Now, I will discuss the simulation results in order to compare them with the behavioural data and to provide further criteria to evaluate my proposal. In this phase of the computational work, I was able to model and simulate only the findings obtained on homonyms. A further version of the model will be implemented to account also polysemy effects.

A neural network is a computational model inspired by animal central nervous systems (in particular the brain). It is usually presented as a system of interconnected "neurons" that can compute values from inputs by feeding information through the network. One of most pervasive uses of neural network regards pattern recognition, that is the classification process of input objects into several classes, based on an automatic matching mechanism of resemblance between objects. In order to execute classification tasks by means of a machine, the real objects (e.g., words) have to be represented by means of numerical values. This operation is called *feature mining* and assigns a univocal pattern to each real object.
A neural network is able to recognize patterns after a training session, where a set of training examples (the training set) has been provided. The set consists of instances (typically vectors) that have been properly labelled by hand with the correct output. A learning algorithm analyses the training data and produces an inferred function, which can be used for mapping new examples. Let us consider an input-output mapping described by:

$$\mathbf{x}\mathbf{y}f=$$

where ***x*** is the input, ***y*** is the output and ***f*** is the unknown function. The typical pattern recognition process is graphically described in Figure 7.2.

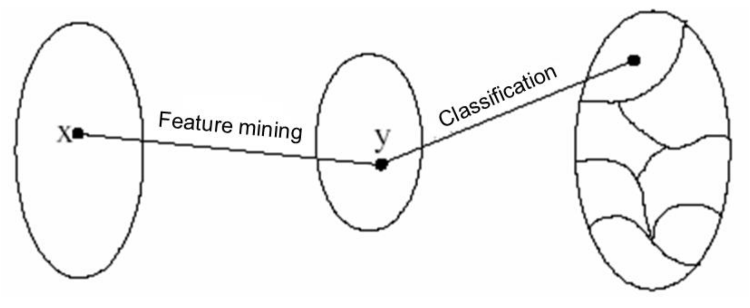


Figura 7.3. Pattern recognition process

An optimal scenario allows the algorithm to correctly determine the class labels for unseen instances, thanks to the intrinsic generalization capability of the neural network. This learning procedure is called “supervised learning”.

7.2 The simulation

7.2.1 Method

Materials. A neural network was implemented by using the pattern recognition method with supervised learning. We selected one hundred seventy-eight items used in my experiments, which included both ambiguous and unambiguous words. Half of them were used for the training phase, half for the testing phase.
All the stimuli were classified in three classes:
"Less" (-): thirty-five ambiguous and unambiguous words for which significant inhibitory effects were reported in behavioural tasks (contrNV= and expNN>);
"Plus" (+): thirty-five ambiguous and unambiguous words for which significant facilitatory effects were reported in behavioural tasks (expNV= and contrNN>);
"Equal" (=): one hundred-eight ambiguous and unambiguous words for which no significant effects were reported in behavioural tasks (expNN=, contrNN=, expN-d, ContrN-d, expV-d e contrV-d).

Each item was labelled for eight variables, which were the same considered in the behavioural tasks:

Rt: average reaction times in milliseconds.
N/tot: the ratio value between the frequency of nominal meaning and the total frequency (both meanings). It is biasing towards 0,50 for N=V words, biasing towards 0 for V>N words, biasing towards 1 for N>V, N>N and N=N. As to control forms, it is always 1 for nouns and 0 for verbs.
Ambiguity: it refers to the semantic feature of having multiple meanings. It is 1 for ambiguous words and 0 for unambiguous words.
GC: it refers to the grammatical ambiguity (e.g., having a nominal meaning and a verbal meaning). It is 1 for N=V, N>V and V>N forms and 0 for N=N words, N>N words and for all control words.
Frequency: it refers to the sum of frequency values reported in CoLFIS for both meanings of homonyms.

Length: number of letters.
N-count: number of orthographic neighbours.

Software. The statistical software R was used to implement the model.

Procedure. In the training phase, a subset of items (training set) was presented to the network with the indication of the right class. In order to allow the network to generalize, the technique of *early stopping*[44] was implemented. Specifically, the training set was split into a new training set and a validation set. Gradient descent was applied to the new training set. After each sweep through the new training set, the network was evaluated on the validation set. When the performance with the validation test stopped improving, the algorithm halted. The network with the best performance on the validation set was then used for actual testing, with a separate set of data.
After the model was optimally trained, new items (testing set) were presented to the network, with the request to assign them the correct class. A comparison between predicted and real outputs is the way to evaluate the network's performance.

7.2.3. Results and discussion

The network's performances on the testing set are graphically reported in Table 7.1.

[44] Early stopping is a simple form of regularization used when a machine learning model (such as a neural network) is trained in order to deal with the problem of overfitting. Overfitting is a phenomenon in which a learning system, such as a neural network, gets very good at dealing with one data set at the expense of becoming very bad at dealing with other data sets.

Classes	-	+	=	Total	Class Error
-	11	0	4	15	0.28
+	0	7	8	15	0.54
=	5	7	30	42	0.29
Total	16	14	42	72	0.31

Table 7.1. The confusion matrix

Each column of the confusion matrix represents the instances in a predicted class, while each row represents the instances in an actual class. In the diagonal the correct outputs are reported. The overall error percentage is 30%. The best performed class is the class "equal" (=), where there is the major number of instances. The reposition analyses allows us to compare simulation pattern and behavioural data. Most items which are incorrectly classified by the model are "borderline" words, with respect to the meaning frequency dominance. Such these items are situated in the middle between the most balanced homonyms (meaning ratio biasing to 0,50) e the most unbalanced homonyms (meaning ratio biasing to 1). Moreover, all the repositions carried out by the network fall down in the class "equal": it never happens that inputs labelled as "plus" are replaced in the class "less" by the model, and vice versa.
Such a rumour on these words was reported in the experiments as well. By correlating the meaning frequency relationship and the effect size reported in the behavioural tasks on a subset of items, it clearly emerges how "borderline" items exhibited a similar pattern of results. A correlation graphic is reported in Figure 7.3.

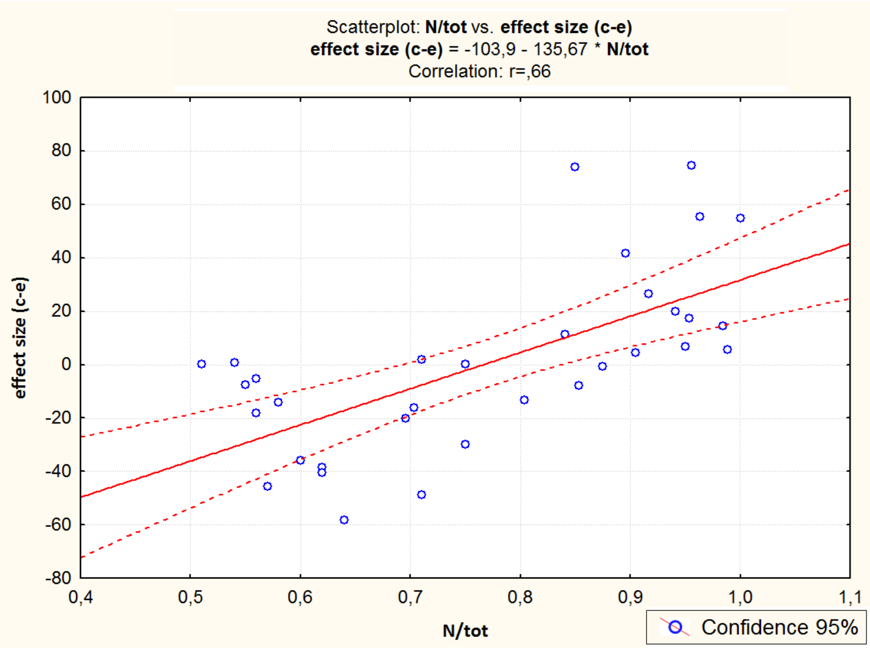


Figura 7.4. The correlation between the meaning dominance and the effect size

In the left side a subset of balanced words (biasing to 0,50 ratio value) is situated: all the effect size values are negative, that means that they exhibit an inhibitory effect. In the right side of the graphic, a subset of unbalanced words (biasing to 1 ratio value) is positioned: in this case the values are especially positive, that means that they exhibit a facilitatory effect. In the central side, intermediate values are reported, as to ratio value and effect size.

7.3. General Discussion

In this part of my research I was interested in implementing a computational model which was able to simulate experimental data obtained on ambiguity effects in single word recognition tasks. Specifically, I started from the results obtained in naming and lexical decision experiments on homonymous words (Experiments 1 and 2). The idea was to evaluate if the theoretical assumptions made to explain my findings were reasonable and accurate enough to work in a formalized model. In a further version of the model, I would like to be able to implement a network to simulate also the results obtained on polysemous words (Experiments 9 and 10).

In the first phase of the implementation work I trained the network by presenting a set of items previously assigned to a specific class and labelled for several variables (the same considered in the experiments). The class assignment was manually operated on the basis of the main size effects reported on each item in the tasks.

After the training step, I submitted new instances to the network, which was asked to assign them the correct class on the basis of statistical resemblances with the training set. The comparison between predicted outputs and real outputs allowed us to evaluate the network performance and analyse the reposition errors.

In general, the pattern of repositions is quite consistent with the experimental data. The most interesting finding is that the network simulates worse items whose meaning frequency relationship is in the middle between the most balanced homonyms and the most unbalanced homonyms. Indeed, this datum is a further evidence of the role played by this variable in processing ambiguous forms.

Another relevant result is that all the repositions fall down in the class “equal”: it never happens that inputs labelled as “plus” are replaced in the class “less” by the model, and vice versa. This is consistent with the behavioural tasks, where on some “borderline” items a null effect was found, instead of an expected facilitatory or inhibitory effect. However, I cannot exclude that the major size of the class “equal” creates a bias to assign the doubtful instances to this class.

The simulative work helped us to evaluate the theoretical assumptions and to highlight which refinements could be necessary to improve my work both behaviourally and computationally.

First of all, it could be helpful to test the network with new items -both ambiguous and unambiguous - which were not investigated in the experiments; this could allow a generalization of the results. A further

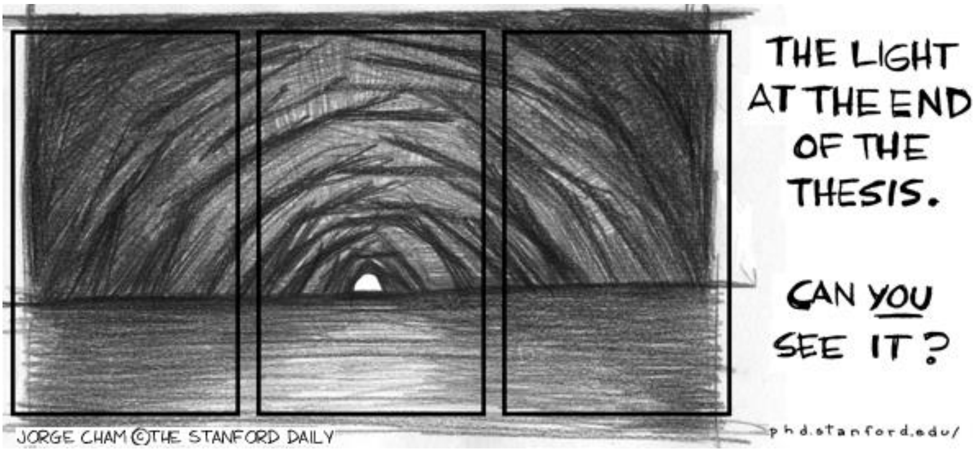
refinement could be obtained by balancing the number of items among classes both in the training and in the testing phases, in order to exclude a bias to the class "equal" in the repositions carried out by the network.
The network accuracy could be improved by avoiding items which are "borderline" in terms of frequency dominance, given that they determined problems in the classification. New behavioural tasks could be also carried out by excluding these items from the experimental material, in order to evaluate if major effect sizes are obtained.
Finally, the model has to be tested with words with related senses, in order to verify if it is able to simulate also polysemy effects.

7.4 CONCLUDING REMARKS

In this chapter I aimed to implement a computational model which was able to simulate with a certain approximation degree the behavioral results reported in the lexical processing of homonymous words (Experiments 1 and 2). Specifically, I was interested in defining a formal model to account different ambiguity effects depending on grammatical class and meaning frequency dominance.

Summing up:

- The development of computational models is increasingly recognized as essential in psycholinguistics, since it motivates theorists to be explicit in their hypotheses and can be used to generate accurate predictions for theoretical models.
- My model is a simple neural network implemented by using a supervised learning algorithm.
- In the testing phase, the network is asked to assign the correct class to unseen instances on the basis of statistical resemblances with the training set.
- The overall network's performance is consistent with behavioral data. The main ambiguity effects are simulated by the model with an accuracy of 70%.
- Further adaptations in the model and perhaps more experiments could allow me to refine also theoretical insights.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CONCLUSIONS

The experiments presented in this thesis were aimed at revisiting lexical ambiguity effects in visual word recognition, by taking into account some variables that were not fully analyzed in previous research on the topic.

Most studies which have addressed the issue of differences in lexical representation and processing between ambiguous and unambiguous words reported heterogeneous patterns of results (see Lupker, 2007 for a review). One possible explanation for such empirical discrepancies is that these studies were not consistent along several methodological aspects.

Considering lexical ambiguity as a unique, homogeneous phenomenon could be confounding, given that, actually, many variables seem to play a crucial role in determining different – and sometimes contradictory - results. In order to clarify the levels of meanings investigated, we should take into consideration issues such as how the meanings are collected, the type of ambiguous words under investigation, the type of non-words used in lexical decisions, the kind of experimental paradigms adopted.

In our experiments, the specific control of all these factors hopefully provided a new perspective to re-evaluate the ambiguity effects in word recognition tasks.

First of all, my data seem to confirm how the ambiguity status of words plays a crucial role in determining different effects. Previous research, whether arguing for or against the existence of an ambiguity advantage effect in word recognition literature, did not systematically take into consideration the semantic relatedness among meanings of ambiguous words. My data seem to provide further empirical evidence for the hypothesis of a psychological reality of the homonymy/polysemy distinction.

Specifically, words with multiple senses are recognized more easily than unambiguous words. Even when no significant effect is reported on polysemous words, what emerges is a bias towards the facilitatory effect. A different pattern of results is reported in experiments on homonymous words: the overall results show no processing difference between homonymous words and unambiguous words in bare word recognition tasks.

These findings are compatible with the results reported by recent research on lexical ambiguity, which found significant processing differences between homonymous and polysemous words, probably due to the fact that these forms are differently stored in the mental lexicon (Beretta, Fiorentino, & Peoppel, 2005; Klepousniotou, 2002; Klepousniotou, 2012; Klepousniotou & Baum, 2007; Rodd et al., 2002).

Homonyms usually arise through historical accidents, by which two different word meanings converge on the same phonological/orthographic representation, or a single word diverges into very different meanings. In contrast, the multiple uses of a polysemous word are related, and clearly arise through a process of extension of similar meanings rather than through an arbitrary historical coincidence (Clark & Clark, 1979; Sweetser, 1990).

Given these differences, it seems reasonable to predict different lexical representation ways and processing mechanisms for the two types of ambiguous words.

As to semantic level, both homonymous and polysemous words are supposed to have more than one representation, each corresponding to the specific meaning/sense they can assume. However, while the multiple representations of polysemous words partially overlap, representations of homonymous words are totally separated.

Thus, when speakers encounter a polysemous word in isolation, what is supposed to happen is that all the semantic representations of that word are activated, because they are connected each other. The consequent spread of activation renders the output representation more available and, thus, facilitates the retrieval process. Instead, in the case of homonymous word recognition, a selection mechanism between distinct representations is expected.

Another aim of this research was to verify if the recognition process of ambiguous forms is affected by factors such as grammatical class, meaning frequency dominance and declensional class which have not been taken into account in most previous experiments on the topic. By manipulating these factors, multiple subsets of both polysemous and homonymous words were obtained.

All in all, the data seem to confirm how these variables seem to deeply affect the lexical representations and processing of ambiguous words.

Single comparisons among multiple subsets of ambiguous words reveal different ambiguity effects. Specifically, one of the most remarkable data is the ambiguity disadvantage effect reported both on homonymous and polysemous words when the ambiguity involves the syntactic level (different parts of speech, e.g., noun and verb such as *abito, inviato*, etc.) and when meaning frequencies are balanced (Experiments 1-2; 9-10).

The same inhibitory effect is found on balanced homonymous nouns belonging to different declensional classes (Exp.4).

On the majority of the other subsets of homonymous words a substantial absence of processing differences in respect to unambiguous words is reported (apart from a facilitatory effect on unbalanced noun-noun words, Experiments 1-2); in the case of polysemous words (Experiments 9-10), a significant facilitatory effect is found in nearly every subset. The processing differences I found seem to reflect different lexical representations among categories of ambiguous items.

Ambiguous words with an alternation either between two grammatical classes (nouns and verbs) or between two declensional classes (-e nouns and –a/-o nouns) are supposed to have two distinct representations at the orthographic input and phonological output lexicon level. These representations compete with each other during lexical access.

Since lexical access is supposedly mediated by relative frequencies of each occurrence of ambiguous words, the competition process will be stronger in the case of balanced ambiguous forms. On the contrary, ambiguous words belonging either to the same grammatical class or to the same declensional class are predicted to have a single representation at this level.

These findings seem to confirm the role played by variables such as meaning dominance, grammatical class and declensional class in determining different ambiguity effects.

Similar results are obtained also in semantic and morphological priming experiments, which were aimed at investigating the lexical processing of homonymous words in presence of such a "contextual" information biasing towards one of two possible meanings of items. By manipulating grammatical class and meaning frequency dominance of the homonyms, indeed, I obtained a modulation of the semantic and morphological priming effects (Experiments 5-8).

Finally, the performance of a computational model was found to be consistent with behavioral data. The main ambiguity effects reported in experiments on homonymous words (Experiments 1-2) were simulated by the network with an accuracy of 70%. Further adaptations in the model and perhaps more experiments would allow me to refine also my theoretical insights. Moreover, the model has also to be tested with words with related senses, in order to verify if it is able to simulate polysemy effects.

In conclusion, the findings seem to show that it is crucial to assume a new methodological perspective in order to investigate the ambiguity effects in word recognition. Only by taking a broader view of the possible factors affecting lexical processing of ambiguous forms we will be able to direct our efforts in order to better understand the lexical ambiguity processing and its relation to other aspects of language comprehension.

My work sheds light not only on lexical ambiguity effects but also on a more general assumption about which information levels are involved in word lexical access. The processing differences among different types of ambiguous words provide a little evidence in favour of the idea that abstract levels ofinformation (such as the grammatical class) would be represented in the input lexicon and necessary accessed even though they are not explicitly required by the task.

The study does not pretend to be considered exhaustive in its attempt to account for empirical discrepancies on the lexical ambiguity effects. Other variables which were not considered in my experiments could play a role in lexical ambiguity processing. The challenge of explaining how ambiguous words are lexically accessed by speakers is still open.

For example, it could be interesting to investigate the effects of lexical ambiguity in language production tasks, in order to evaluate if the model of lexical access works in the reversed process as well. A possible way to explore this issue could be to carry out some picture naming experiments, where the production of words referring to vague, “polysemous” concepts (e.g., *to cook*) is compared to the production of words referring to specific concepts (e.g., *to fry*).

Another remarkable research field is the lexical processing by bilingual speakers of the so-called ‘interlingual non-cognate homonyms’, that is words with multiple meanings in different languages (e.g., the English word ‘spot’, which in Dutch means *ridicule*). These stimulus materials have been mostly used in studies which have focused on how bilinguals represent words from two distinct systems and on whether or not lexical representations in one language activate those of the other. Despite the great number of attempts to address the issue, there is yet no agreement about how these words are stored and processed in the bilingual mental lexicon (De Groot, Del- maar, & Lupker, 2000; Dijkstra et al., 1998; Gerard & Scarborough, 1989; Von Studnitz and Green, 2002). Thus, it could be helpful to revisit the interlingual homonymy effects by taking into account variables such as the meaning frequency dominance and the grammatical class.

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Appendix

Stimuli used in Experiments 1 & 2

expV>N	contrV>N	expN>V	contrN>V
accetta	accade	abito	abbondanza
amo	apre	aspetti	ala
calcare	colse	bara	baia
cerchi	circonda	cancello	canzone
compare	compie	collega	collo
costato	copre	contesto	contessa
fate	finire	esiti	esempi
feci	fissare	imposta	impulso
insegna	andava	leva	lezione
lancia	linciare	mento	manzo
regge	reso	mostro	modi
saliva	sarei	parete	pane
scaglia	scatta	parto	perdite
sedere	sogna	poste	poeta
serve	sorge	tappa	tavoli
taglia	tace	temi	testimone
tende	tenta	tessere	torre
trovata	trascina	testata	tela

expN>N	contrN>N	expN=N	contrN=N
asta	agio	canone	canale
bande	bancone	caratteri	cabina
calzoni	coltello	cartone	corvo
campione	compagno	credenza	credito
cartello	cortile	dote	dolori
fattore	fama	maglie	malore
fiasco	fiaba	merli	Merce
gru	grano	pila	Pirate
marmo	mercati	pizzo	Piste
materia	mattino	portieri	Partenze
miglio	motto	ratto	Rottame

pensione	pancia	rigore	ricette
piante	piede	sigle	Sisma
polo	polmone	sirena	Sicario
salsa	soldati	stadi	Statue
sesso	sede	tenore	Telaio
tasso	tetto	vespe	Vene
usura	umore	viole	Viali

expN=V	**contrN=V**	**contrV=N**
calca	calze	calmato
date	dadi	dona
fungo	fango	fondere
lava	lacci	litiga
maneggio	maga	maturare
mira	miniera	metto
molla	mole	moriva
notai	noce	nega
paia	paste	pago
parato	palato	porre
raso	rame	ragiona
resti	reti	ride
spartito	sporcizia	sparge
straccio	strofa	strilla
stufato	stelo	stira
suole	suora	suona
supposta	supplenze	suda

Stimuli used in Experiment 3

N>V	**V>N**	**N=V**
abito	accetta	bucato
bara	amo	calca
*	assunto	costa
cancelli	balla	cozza
collega	cala	crepa

contesti	calcare	danno
esiti	cerchi	date
giunta	compare	divisa
letti	costato	fungo
mento	curato	imposta
monti	deriva	lava
mostri	fate	messa
paia	feci	notai
parto	insegna	parato
perito	lancia	posta
posate	passata	spartito
procura	regge	stufato
raso	saliva	suole
riviste	scaglia	supposta
tessere	spira	taglia

*The item 'boccia' was removed from analysis

Stimuli used in Experiment 4

expN=N	**contrN=N**	**expN>N**	**contrN>N**
assi	aghi	arti	armi
botte	burro	colli	coppe
folle	ferro	conti	carta
messe	motto	generi	genesi
moli	mito	latte	lusso
pene	pelo	menti	multe
pesti	pegni	monte	merce
sale	seme	parti	ponti
teste	tasca	primati	profilo
vite	vizi	sete	seno

Stimuli used in Experiment 5

Type	Contr. prime	Exp. prime	Target
N>V	foresta	vestito	**abito**
N>V	chiome	sembianze	**aspetti**
N>V	senso	morte	**bara**
N>V	esigenza	entrate	**cancelli**
N>V	sangue	ufficio	**collega**
N>V	abbonamenti	situazione	**contesto**
N>V	parlamento	risultati	**esiti**
N>V	acciaio	tassa	**imposta**
N>V	amici	forza	**leva**
N>V	aria	viso	**mento**
N>V	crisi	paura	**mostri**
N>V	cena	muro	**parete**
N>V	romanzo	nascita	**parto**
N>V	maestro	uffici	**poste**
N>V	scena	viaggio	**tappa**
N>V	obiettivo	argomenti	**temi**
N>V	chiavi	schede	**tessere**
N>V	limiti	giornale	**testata**
V>N	orme	ascia	**accetta**
V>N	frasi	pesci	**ami**
V>N	sepoltura	lavandino	**calcare**
V>N	sondaggio	quadrati	**cerchi**
V>N	spettacolo	matrimonio	**compare**
V>N	rami	ossa	**costato**
V>N	gola	nave	**deriva**
V>N	opulenza	turchine	**fate**
V>N	gesuiti	escrementi	**feci**
V>N	cifra	negozio	**insegna**
V>N	spiriti	scudo	**lancia**
V>N	sentinelle	imperatori	**regge**
V>N	guida	bocca	**saliva**
V>N	apparenza	formaggio	**scaglia**
V>N	tigli	schiave	**serve**
V>N	giudizio	misura	**taglia**

V>N	racconto	finestra	**tende**
V>N	preferenze	invenzione	**trovata**
N=N	prova	carta	**asso**
N=N	esperienza	televisione	**canone**
N=N	spavento	alfabeto	**caratteri**
N=N	palazzo	scatola	**cartone**
N=N	nemico	religione	**credenza**
N=N	piazza	pregio	**dote**
N=N	castello	vestiti	**maglie**
N=N	casse	uccelli	**merli**
N=N	antefatti	elettricità	**pila**
N=N	affissioni	merletto	**pizzo**
N=N	trofeo	topo	**ratto**
N=N	pittori	fermezza	**rigore**
N=N	ospiti	canzoni	**sigle**
N=N	motivi	allarme	**sirena**
N=N	trattazione	tifoseria	**stadi**
N=N	streghe	soprano	**tenore**
N=N	dettaglio	insetti	**vespe**
N=N	figli	fiori	**viole**
N>N	scienze	quercia	**albero**
N>N	orgoglio	vendite	**aste**
N>N	enti	pantaloni	**calzoni**
N>N	ipocrisia	fuoriclasse	**campioni**
N>N	appuntamento	malattia	**cancro**
N>N	desiderio	elemento	**fattore**
N>N	clima	vino	**fiasco**
N>N	archivio	sigaretta	**filtro**
N>N	vedovo	unioni	**leghe**
N>N	ladri	guaio	**pasticcio**
N>N	interviste	vecchiaia	**pensione**
N>N	gestione	estremo	**polo**
N>N	fulmine	pomodoro	**salsa**
N>N	parola	fame	**sete**
N>N	attimi	palude	**stagno**
N>N	timbro	cotone	**stoffa**

N>N	zanzariera	strozzini	**usura**
N>N	scorze	arteria	**vena**
N<N	frase	nave	**albero**
N<N	onore	bandiere	**aste**
N<N	saune	pizze	**calzoni**
N<N	scheletri	statistica	**campione**
N<N	giardiniere	sagittario	**cancro**
N<N	atmosfera	contadino	**fattore**
N<N	testimone	fallimento	**fiasco**
N<N	ceretta	pozione	**filtro**
N<N	brace	metalli	**leghe**
N<N	camicette	timballo	**pasticcio**
N<N	vertice	albergo	**pensione**
N<N	emozioni	maglia	**polo**
N<N	pietre	ballo	**salsa**
N<N	stupore	tessuti	**sete**
N<N	carote	rame	**stagno**
N<N	alleati	talento	**stoffa**
N<N	paghe	logorio	**usura**
N<N	soffitto	ispirazione	**vena**
N=V	ritmo	folla	**calca**
N=V	aria	mese	**date**
N=V	camorra	vulcano	**lava**
N=V	teppisti	tartufo	**fungo**
N=V	ironia	cavalli	**maneggio**
N=V	prudenza	bersaglio	**mira**
N=V	flussi	elastico	**molla**
N=V	anticipo	avvocati	**notai**
N=V	museo	scarpe	**paia**
N=V	fretta	muro	**parato**
N=V	gomme	stoffa	**raso**
N=V	vomito	residui	**resti**
N=V	fuoco	musica	**spartito**
N=V	aghi	pezza	**straccio**
N=V	edilizia	verdure	**stufato**
N=V	spazi	scarpe	**suole**

N=V	corridoi	febbre	**supposta**

Stimuli used in Experiment 6

Type	Contr. prime	Exp. prime	Target
N>V	abete	**abito**	vestito
N>V	bile	**bara**	funerale
N>V	canzone	**cancelli**	portoni
N>V	collana	**collega**	ufficio
N>V	consensi	**contesto**	scenario
N>V	esodo	**esiti**	risultati
N>V	museo	**mento**	viso
N>V	modi	**mostri**	paura
N>V	panico	**parete**	quadro
N>V	perle	**parto**	nascita
N>V	ponte	**poste**	bollette
N>V	proposta	**procura**	magistrato
N>V	ricordo	**riviste**	giornali
N>V	terapia	**tappa**	meta
N>V	terre	**temi**	argomenti
N>V	terrore	**tessere**	schede
V>N	accade	**accetta**	ascia
V>N	apri	**ami**	pesci
V>N	cenare	**cerchi**	quadrati
V>N	compio	**compare**	anello
V>N	corro	**costato**	petto
V>N	dovevi	**deriva**	nave
V>N	finire	**fate**	magia
V>N	ferisce	**feci**	escrementi
V>N	indaga	**insegna**	negozio
V>N	leggiamo	**lancia**	scudo
V>N	sarei	**saliva**	bocca
V>N	scopro	**scaglia**	parmigiano
V>N	sorge	**serve**	schiave
V>N	tira	**taglia**	grandezza
V>N	tenta	**tende**	finestra

V>N	trascura	**trovata**	idea
$N=N_1$	cabina	**canone**	abbonamento
$N=N_1$	cadaveri	**caratteri**	alfabeto
$N=N_1$	corda	**cartone**	scatola
$N=N_1$	cravatta	**credenza**	religione
$N=N_1$	duca	**dote**	pregio
$N=N_1$	masse	**maglie**	indumenti
$N=N_1$	pirata	**pila**	elettrica
$N=N_1$	piste	**pizzo**	merletto
$N=N_1$	rasoio	**ratto**	topo
$N=N_1$	ricette	**rigore**	tiro
$N=N_1$	sisma	**sigle**	canzoni
$N=N_1$	stomaco	**sirene**	mare
$N=N_1$	statue	**stadi**	tifosi
$N=N_1$	telaio	**tenore**	soprano
$N=N_1$	teglia	**testata**	giornale
$N=N_1$	voce	**vespa**	ape
$N=N_2$	calibro	**canone**	criterio
$N=N_2$	canale	**caratteri**	persone
$N=N_2$	carceri	**cartone**	animato
$N=N_2$	critiche	**credenza**	cucina
$N=N_2$	dolori	**dote**	sposa
$N=N_2$	maga	**maglie**	reticolo
$N=N_2$	pipe	**pila**	torcia
$N=N_2$	pinne	**pizzo**	mafia
$N=N_2$	razza	**ratto**	sabine
$N=N_2$	risate	**rigore**	disciplina
$N=N_2$	signora	**sigle**	iniziali
$N=N_2$	sabbia	**sirene**	allarme
$N=N_2$	stelo	**stadi**	livelli
$N=N_2$	tegame	**tenore**	vita
$N=N_2$	terapie	**testata**	colpo
$N=N_2$	vermi	**vespa**	motocicletta
N>N	agio	**aste**	vendite
N>N	calvario	**calzoni**	pantaloni
N>N	commercio	**campioni**	vittoria

N>N	cannone	**cancro**	tumore
N>N	fama	**fattore**	matematica
N>N	fiaba	**fiasco**	fallimento
N>N	lode	**leghe**	unioni
N>N	molecola	**materia**	scuola
N>N	parroco	**pasticcio**	guaio
N>N	pori	**polo**	nord
N>N	soldati	**salsa**	pomodoro
N>N	sede	**sesso**	amore
N>N	stazza	**stagno**	lago
N>N	storie	**stoffa**	tessuto
N>N	umore	**usura**	strozzini
N>N	vagone	**vena**	sangue
N<N	ago	**aste**	bandiere
N<N	caldaie	**calzoni**	pizze
N<N	cantieri	**campioni**	analisi
N<N	candore	**cancro**	oroscopo
N<N	facciata	**fattore**	contadino
N<N	fiamma	**fiasco**	vino
N<N	linfa	**leghe**	metalli
N<N	mattino	**materia**	sostanza
N<N	pazienza	**pasticcio**	torta
N<N	pausa	**polo**	maglia
N<N	salme	**salsa**	ballo
N<N	sacco	**sesso**	maschile
N<N	stelle	**stagno**	alluminio
N<N	stucco	**stoffa**	talento
N<N	urina	**usura**	consumato
N<N	vele	**vena**	ispirazione
N=V	calze	**calca**	folla
N=V	dona	**date**	nascita
N=V	forno	**fungo**	montagna
N=V	istanza	**imposta**	tassa
N=V	litiga	**lava**	vulcano
N=V	maturare	**maneggio**	cavalli
N=V	mode	**molla**	elastico

N=V	nega	**notai**	avvocati
N=V	panini	**parato**	carta
N=V	ridi	**resti**	scarti
N=V	sporcizia	**spartito**	musica
N=V	strilla	**straccio**	pezza
N=V	stupore	**stufato**	verdure
N=V	segue	**suole**	scarpe
N=V	superfici	**supposta**	febbre

Stimuli used in Experiment 7

Type	**Contr. prime**	**Exp. prime**	**Target**
N>V	rivelata	abitata	**abito**
N>V	replicato	aspettato	**aspetti**
N>V	volare	barare	**bara**
N>V	spostato	cancellato	**cancelli**
N>V	piaciuta	collegata	**collega**
N>V	dormito	esitato	**esiti**
N>V	vestire	mentire	**menti**
N>V	donare	montare	**monti**
N>V	calcolato	mostrata	**mostri**
N>V	cedeva	pareva	**parete**
N>V	ricordiamo	partiamo	**parto**
N>V	intuire	perire	**perito**
N>V	citare	posare	**posate**
N>V	scaricare	procurare	**procura**
N>V	lasciata	stracciata	**straccio**
N>V	vigeva	tesseva	**tessere**
N>V	lodare	testare	**testata**
V>N	accettata	dedicata	**accetta**
V>N	amate	violate	**amo**
V>N	ballato	temuto	**balla**
V>N	bocciato	attaccato	**boccia**
V>N	calare	rubare	**cala**
V>N	calcava	usciva	**calcare**
V>N	comparire	scivolato	**compare**

V>N	costare	sudare	**costato**
V>N	curare	svelare	**curato**
V>N	derivare	coltivare	**deriva**
V>N	faremo	andremo	**fate**
V>N	insegnati	provati	**insegna**
V>N	passavo	osavo	**passata**
V>N	reggeva	giocava	**regge**
V>N	saliti	basati	**saliva**
V>N	scagliare	lacrimare	**scaglia**
V>N	trovi	basti	**trovata**
N=V	bucare	vietare	**bucato**
N=V	calcato	fallito	**calca**
N=V	costava	finiva	**costa**
N=V	crepato	gradito	**crepa**
N=V	dava	correva	**danno**
N=V	darete	vedrai	**date**
N=V	fungere	vincere	**fungo**
N=V	lavato	cantato	**lava**
N=V	supponeva	cominciava	**supposta**
N=V	mollato	sperato	**molla**
N=V	notato	tradito	**notai**
N=V	parare	tritare	**parato**
N=V	restata	basata	**resti**
N=V	spartire	ferire	**spartito**
N=V	stufare	dotare	**stufato**
N=V	tagliate	suonate	**taglia**
N=V	tendere	punire	**tende**

Stimuli used in Experiment 8

Type	Contr. prime	Morph. prime	Exp. prime	Target
N>V	vincere	abita	**abito**	abitata
N>V	naviga	aspetta	**aspetti**	aspettato
N>V	chiamati	barato	**bara**	barare
N>V	muovi	cancella	**cancelli**	cancellato
N>V	puntato	collego	**collega**	collegata

N>V	correre	esita	**esiti**	esitato
N>V	viveva	monto	**monti**	montare
N>V	pensi	mostrare	**mostri**	mostrata
N>V	creata	pare	**parete**	pareva
N>V	cuoce	partire	**parto**	partiamo
N>V	sentita	periva	**perito**	perire
N>V	togliamo	posato	**posate**	posare
N>V	contato	procuri	**procura**	procurare
N>V	osa	straccia	**straccio**	stracciata
N>V	chiama	tappato	**tappa**	tappare
N>V	intuire	tesse	**tessere**	tesseva
N>V	preghi	testati	**testata**	testare
V>N	cambia	accetto	**accetta**	accettata
V>N	nasce	ama	**amo**	amate
V>N	sente	ballava	**balla**	ballato
V>N	butta	calato	**cala**	calare
V>N	aiuta	calcato	**calcare**	calcava
V>N	svolgere	cerco	**cerchi**	cercata
V>N	trattava	compariva	**compare**	comparire
V>N	lasci	costava	**costato**	costare
V>N	sogna	curo	**curato**	curare
V>N	bastata	derivi	**deriva**	derivare
V>N	dicevo	farei	**fate**	faremo
V>N	contiene	insegni	**insegna**	insegnati
V>N	citava	lanciare	**lancia**	lanciata
V>N	evitato	passa	**passata**	passavo
V>N	bevo	salire	**saliva**	saliti
V>N	ripeto	scagli	**scaglia**	scagliare
V>N	prendi	servire	**serve**	servite
V>N	succhia	trovi	**trovata**	troveremo
N=V	colpita	bucata	**bucato**	bucare
N=V	spicca	calcava	**calca**	calcato
N=V	nate	costare	**costa**	costava
N=V	premia	cozzo	**cozza**	cozzare
N=V	vedi	crepo	**crepa**	crepato
N=V	riesce	davamo	**danno**	dava

N=V	lottato	darei	**date**	darete
N=V	inviata	funge	**fungo**	fungere
N=V	rubi	lavo	**lava**	lavato
N=V	ringrazia	supponi	**supposta**	supponeva
N=V	fondava	mollo	**molla**	mollato
N=V	pensavo	notare	**notai**	notato
N=V	udita	parava	**parato**	parare
N=V	tradito	resta	**resti**	restata
N=V	viste	spartita	**spartito**	spartire
N=V	cado	stufata	**stufato**	stufare
N=V	loda	tagliare	**taglia**	tagliate
N=V	odia	tendi	**tende**	tendere

Stimuli used in Experiments 9 & 10

expN>V	**contrN>V**	**expV>N**	**contrV>N**
ballata	bottone	affronti	afferma
bandito	bimbo	condensa	compie
certificati	certezza	conserva	considera
condanna	convegno	conta	convive
copia	comitato	creato	cresciuta
cura	carota	credo	gratta
danza	drago	dedica	dichiara
dimora	disastro	deriva	diventa
guida	guai	giocata	gestiti
misura	motori	giurato	girato
racconto	ragazze	grida	grava
rischi	regista	paga	pone
Scavi	scorie	pensata	perdete
scherzo	scandalo	portate	pongo
soccorso	sonno	raccolto	restare
spavento	statua	recita	ridere
sposo	stipendio	trovata	tramare
telefoni	tisane	vissuti	vale

expN=N	contrN=N	expN>N	contrN>N
astro	ascia	allarme	allegria
bagaglio	bacheche	armonia	argilla
battesimo	bottiglie	cattedra	corridoio
bersaglio	borghesia	cotone	cognome
cornice	carbone	incubo	infanzia
impresa	inverno	limone	luna
macchine	mattinata	matassa	madri
miniera	matrimoni	medicina	mela
mosaico	miracolo	nervi	norme
nastri	narici	padiglione	pericoli
pallone	petto	pollo	parroco
portieri	porpora	ponte	panca
radici	ragno	regina	reddito
scoglio	scatola	rubrica	ristorante
soglia	senatore	talento	topo
sorgente	sarto	tensione	tempio
verbo	vernice	trappola	trattativa
vetrina	vigna	trono	tragitto

expN=V	contrN=V	contrV=N
ascolti	asfalto	appartiene
bolle	bicicletta	soffiare
comunicato	casalinga	conosciuto
conferma	candele	conclude
diffida	dollari	diffonde
durata	docente	dovuta
inviato	inferno	imparato
mira	magia	merita
odio	ozono	ama
pronuncia	prezzi	procede
ricevuta	revisione	ricorre
rinuncia	rughe	rischiato
sbagli	spada	sbuca
spaccato	stivali	sparato

tracciato	treccia	tradito
udito	utopia	uscito
urla	armatura	urta
verifica	valigia	vedi