1. INTRODUCTION

1.1. An introductory example

Over 25 years ago, Healy and Miller (1970) asked participants to sort 25 sentences into five piles. The sentences were simple active SVO (Subject – verb – Object) sentences. Each of which was composed of one of five different Subjects (the salesman, the critic, the writer, the student, the publisher), one of five different verbs (sold, criticized, wrote, studied, published), and a Direct Object (the book). The five cards with the most plausible combination of Subject and verb (e.g., The salesman sold the book) were given as starting cards for five different piles. The participants were told to sort the remaining 20 cards on the basis of sentence meaning, with the restriction that in the end, each pile had to consist of five cards. It was found that participants grouped sentences with the same verb more often than sentences with the same person: 16 out of 20 participants used identical verbs in each pile. On the basis of these results, the authors concluded that the verb is the main determinant of sentence meaning.

1.2. This chapter

This chapter will begin by discussing the importance of verbs during sentence processing and thus the relevance of studying verbs. Following this, several general methodological issues pertaining to psycholinguistic research will be discussed, and related to the present study.

2. WHY ARE VERBS IMPORTANT?

2.1. Verbs dominate the sentence

As can be learned from the introductory example, the verb is the core of a sentence and ‘governs’ both the semantic and the syntactic information available in a sentence. Verbs have important relations with the other word categories in a sentence: for example, adverbs modify verbs, the verb introduces prepositional phrases, and in terms of nouns, the verb provides the number of entities (persons or objects) involved in the event
(argument structure), the type of entities (subcategorization frame) and the relation between these entities and the verb itself (theta role assignment). The verb plays a major semantic role as well: it expresses the event that the sentence describes (by its proper meaning).

The special role of verbs compared to nouns is reflected in many different studies using a wide variety of methodologies. For example, when participants were asked to memorize two nouns, performance on a recognition task was better for nouns that were imagined in a scene in which the two objects interacted in some way (in other words, were linked via a verb or event), compared to a scene in which the two objects were present as two independent entities (Bower, 1970). The fact that the verb is the semantic core of the sentence is demonstrated in rating and sorting tasks, such as the one discussed previously (Healy & Miller, 1970). Also, eye movement data revealed that the verb receives more visual attention than other elements in a simple Subject-Verb-Object sentence (Rayner, 1977), indicating the important role of the verb in sentence processing. Finally, Gladney and Kruee (1967) found that readers experienced more difficulty interpreting a sentence in which the verb had been replaced (by an adverb or adjective) than when a Subject or Object noun was replaced. Similarly, removing a verb from a sentence reduced the grammatical acceptability of a sentence more than removing a noun did (Healy & Miller, 1971).

2.2. **Verbs are complex**

In addition to the important role that verbs play in a sentence, verbs also seem to have an inherent complexity, which is reflected in psycholinguistic measures as well as in language acquisition and language impairments. Memory for verbs has repeatedly been shown to be poorer than memory for nouns. For example, when participants are asked to recall words presented in lists, performance for nouns is better than for verbs (Engelkamp, Zimmer, & Mohr, 1990). Also, when participants have to remember action phrases, verbs are recalled much worse than Subject and Object nouns (Clark, 1966; Horowitz & Prytulak, 1969) and are substituted more often (Earles, Kersten, Turner, & McMullen, 2005). Furthermore, in a lexical decision task (where participants have to respond to a target with a word/non-word decision) reaction times for verbs are slower than reaction times for nouns (Baayen, Dijkstra, & Schreuder, 1997; Haan, Streb, Bien, & Rösler, 2000; Rösler, Streb, & Haan, 2001). Rösler et al. (2001) compared priming effects for verb pairs and noun pairs with the same mean similarity rating (as measured in a pretest) and the same

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1 For an explanation of argument structure, subcategorization frames and theta roles see Chapter 4, section 1.2.
2 People can determine more rapidly that a string of letters (the probe) is a word when it follows a related word (the prime) than when it follows an unrelated word (Meyer & Schvanefeldt, 1971).
mean word frequency. They not only found that the reaction times for verbs were on average 30 ms slower, but also that the error rate for verbs was higher than for nouns and that the priming effect between verbs was less strong than the priming effect between nouns.

Verbs are acquired relatively late (Bassano, 2000; Gentner, 1978; Gleitman, 1994; Marshall, 2003), and these early noun advantages in acquisition seems to be universal: Even in a language with input properties that seem to favor verbs, like Korean (verb-final, allows pro-drop) or Mandarin (which has no morphology on either verbs or nouns, whereas in many other languages the verb is morphologically more complex), early noun-dominance has been reported (Gentner, 2006 and references therein). Also, in an experimental setting, young children produced novel nouns more often than novel verbs and used them in a greater variety of contexts in an elicitation study (Tomasello, Akhtar, Dodson, & Rekau, 1997). Finally, children with specific language impairment (SLI) and adults with (Broca’s) aphasia encounter difficulties with action naming, have a reduced vocabulary of verbs, and prefer highly frequent, semantically empty, ‘light’ verbs and simple syntactic structures in which verbs do not require inflections (Bastiaanse & Jonkers, 1998; Bastiaanse & Bol, 2001; Berndt, Mitchum, Haendiges, & Sandson, 1997; Berndt, Haendiges, Mitchum, & Sandson, 1997; Conti-Ramsden & Jones, 1997; De Jong, 1999; Fletcher, 1992; Kemmerer & Tranel, 2000; Kim & Thompson, 2000; Rice & Bode, 1993; Thompson, Lange, Schneider, & Shapiro, 1997).

3. STUDYING LANGUAGE PROCESSING

3.1. Introduction

The studies presented in this dissertation aim to resolve issues regarding on-line comprehension of spoken sentences. First, the difference between on-line and off-line tasks and the advantages and disadvantages of studying spoken (as opposed to written) language comprehension are discussed. Next, four paradigms are presented that are used to address questions about on-line spoken sentence comprehension.

3.2. On-line versus off-line tasks

The card-sorting experiment described in section 1.1 reveals very interesting information about the role of the verb as part of the sentence. Nevertheless, it is not clear what strategies and processes played a role during the task. Also, we cannot be sure that there is any relation between the strategies participants used to solve this card sorting task and the ‘strategies’ they use when processing a sentence in daily life.
In psycholinguistics, many different experimental paradigms are employed to study human language processing. The tasks that are used can be roughly divided into two different classes: off-line and on-line tasks. Off-line tasks measure effects at the end-point of a whole series of processes. Also, they often require participants to make conscious decisions about language or engage in some kind of problem solving. As a result, memory-related, metalinguistic and/or attentional processes come into play. The most common off-line tasks in the sentence processing field are sentence-picture matching, grammaticality judgements, sentence repetition, sentence recall, and paraphrase tasks. A serious limitation is that in off-line tasks the answer or response is inevitably the sum of many different (language and other) processes and the influence of each of these processes cannot be disentangled. In conclusion, off-line tasks are not very suitable for addressing more detailed questions about the **how** of ongoing processes.

On-line tasks answer questions about **when** and **how**. For example: When is the relevant meaning of an ambiguous word selected? These tasks tap into temporal, on-going language processes. Examples of on-line tasks are: word-by-word (self paced) reading, eye-tracking, cross-modal lexical priming, and paradigms using event related brain potentials (ERPs). The results of on-line tasks reflect fast-acting, automatic processes as they unfold over time, and thus may be argued to measure language processing in a more natural way. Some on-line tasks make an appeal to processes other than mere comprehension too. For example, the self-paced reading paradigm is often combined with a grammaticality or plausibility judgement, which results in a less natural way of language processing, with an explicit focus on aspects one would probably ignore during normal sentence processing. When reading a book, or having a conversation, the grammaticality or plausibility of sentences is in general taken for granted. Although many people will notice typos or mispronunciations, this is only a spin-off effect and cannot be equated to the active, conscious monitoring strategies that participants in, for example the ‘stops-making-sense’ task, are engaged in.

Clearly, both off-line and on-line tasks add relevant knowledge about language comprehension. For example, the results of off-line tasks often pave the way for on-line tasks by establishing general patterns and generating further questions to be answered using on-line paradigms. Which kind of task is preferred depends on the research question at hand. Since the focus in the present study is on **how** listeners understand sentences and on disentangling different processes (or at least the influence of difference factors inherent to verbs) that occur during sentence comprehension, an on-line paradigm will be used.

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3 Although someone could easily argue that asking a person if she understands what you just said is perfectly ‘natural’.

4 In this task, participants have to press a button as soon as the sentence they are reading becomes ungrammatical or implausible (e.g., Boland, Tanenhaus, Garnsey, & Carlson, 1995).
3.3. Spoken versus written language

Although many effects found in written language comprehension are replicated in spoken sentence comprehension, there are some important differences. This is mainly due to the availability of prosodic information, which in spoken language may aid in avoiding structural ambiguities (Beach, 1992; Nagel, Shapiro, Tuller, & Nawy, 1996). Nevertheless, understanding spoken language has its challenges as well. For example, written language is strictly linear and clearly segmented: characters, words and sentences have discrete boundaries. On the other hand, phonemes overlap and are co-articulated, and word and phrase boundaries are not marked in spoken language. In faster speech, even clause and sentence boundaries tend to be neglected. Also, whereas readers have often been found to slow down or speed up the input of written text depending on the complexity level of specific words or constructions (Clifton, Speer, & Abney, 1991; Rayner, 1977; Tanenhaus & Spivey-Knowlton, 1996), a listener can typically not control the rate at which information comes in.

In the (psycho-)linguistic literature, a great majority of studies on comprehension have employed visually presented materials. Possible reasons for this are that the use of written stimuli is easier, less time consuming and does not require sophisticated equipment. Also, written language can be better controlled. Prosody is only recently becoming an area of interest in linguistic research, and not enough is yet known to evaluate which prosodic variables are important and may need to be controlled. Finally, perhaps the most important reason why written language has been studied more often than spoken language is the availability of suitable tasks. Only very recently, the arsenal of tasks to study spoken sentence comprehension has begun to expand.

Despite all these counter arguments to studying spoken language, reading is often considered to be a second-order phenomenon; for example, language acquisition always starts with listening and speaking and not with reading and writing, also, there are cultures that do not have written languages. Thus it could be argued that spoken (and signed) languages may be a primary outcome of language, while reading is not.

The focus of the present study is on spoken sentence processing, therefore four promising (on-line) paradigms will be discussed in the next section.

3.4. Paradigms to study on-line spoken sentence processing

A recently developed paradigm is the visual world paradigm, an adaptation of the eye-tracking technique used in written sentence processing. In this task, eye movements of

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5 Although it is quite sophisticated to take eye fixation measures during reading, for example.
participants are tracked while they study a visual scene consisting of (pictures of) different objects (e.g., Altmann & Kamide, 1999; Kamide, Altmann, & Haywood, 2003; Knoeferle, Crocker, Scheepers, & Pickering, 2005). These scenes are visible while participants listen to a sentence. Visual world experiments are especially suitable for studying processes related to concrete objects, as these can be easily depicted, and the task has, for example, been used to demonstrate predictive processing during sentence comprehension.

Another paradigm that is used frequently is the event related potentials (ERP) paradigm, in which EEG brain recordings are made during sentence processing. Although this paradigm was only used in combination with relatively slow word-by-word reading during the early years (Van Petten & Kutas, 1990), the technique has been improved such that the application to spoken sentence comprehension tasks is fairly common nowadays (e.g., Van Berkum, Zwitserlood, Hagoort, & Brown, 2003; Haarmann, Cameron, & Ruchkin, 2002). This paradigm is particularly useful for measuring responses to different types of violations and has a very high temporal resolution.

The most widely used paradigm in written sentence comprehension, the self-paced reading paradigm, nowadays also has its auditory counterpart: the auditory moving window technique (Ferreira, Henderson, Anes, Weeks, & McFarlane, 1996). Naturally spoken sentences are recorded and cut into pieces fragment by fragment (or word by word). Participants push a button to hear the next fragment until the end of the sentence, after which they answer a comprehension question. The task can be used to answer questions similar to the ones studied with the widely used visual variant, providing a moment-to-moment profile of processing load across a sentence. Unfortunately, the paradigm has been used infrequently, so the validity cannot be fully assessed. A disadvantage is that the task is somewhat unnatural: as discussed before, word boundaries are not always clearly marked in spoken language, therefore, cutting the materials word by word or fragment by fragment sometimes results in words that cannot easily be identified without the preceding or following word. Further disadvantages are the same as in the self-paced reading paradigm: the input rate is relatively slow and non-fluent, possibly allowing information to be used in ways not typical of ‘normal’ listening (Clifton et al., 1991), the segmentation chosen (either word-by-word or fragment-by-fragment) is always artificial, and, as pressing a button to unfold a sentence is an unnatural procedure for most participants, it is subject to experiment-specific strategies, as well as participant-specific strategies (for example, participants can often move into a fluent cadence while performing continuous button presses).

Finally, the cross-modal lexical priming (CMLP) paradigm (Swinney, Onifer, Prather, & Hirshkowitz, 1979) is used to investigate the activation levels of word meanings at various points during spoken sentence processing. In this paradigm, the main task of participants is to listen to sentences for comprehension. Once in each sentence a letter string is presented
on a screen and a lexical decision (word/non-word) has to be made. The task is based on
the semantic or associative priming effect: people can determine more rapidly that a string
of letters (the probe) is a word when it follows a related word (the prime) than when it
follows an unrelated word (Meyer & Schvanefeldt, 1971).

4. THE PRESENT STUDY

Because of the central role of verbs (see section 2.1), theories of sentence processing
have long acknowledged the need for explicit details of verb activation and integration.
Interestingly, while much research over the years has demonstrated that verb information
plays a crucial role in sentence processing, there is a surprising paucity of evidence detailing
the precise nature of how and when such information is employed. For example, it is well
established that when verbs are encountered during sentence comprehension, their
argument structure configurations and thematic properties are immediately activated
(Chapter 4). However, only few details are known about the role of the verb throughout
the ongoing integration of sentential material prior to final sentence interpretation.

The work presented in this dissertation is aimed at filling part of this void, with the
specific goal of detailing the nature of activation of verbs throughout the process of
sentence comprehension. To learn more about immediate, rapid, unconscious sentence
processing (as it supposedly occurs during natural conversations), a task should be chosen
that requires participants to understand the sentences but that does not require any explicit
judgement on any element of the sentences itself. Furthermore, since the area of interest to
be studied is verb activation, the task needs to be able to track down these activation
processes.

The CMLP technique provides a sensitive reflection of the activation of word
meanings during ongoing sentence comprehension (Love & Swinney, 1996; Nicol, 1993;
Swinney, 1979; Tanenhaus, Carlson, & Seidenberg, 1985). It is a flexible technique, because
the visual probes can be presented at virtually all places during the course of a sentence,
and thus, moment-by-moment (on-line) activation patterns can be accurately tracked
during ongoing sentence comprehension. Finally, since the sentences are presented without
interruption, and no secondary task is involved at least until the point of interest, there is
relatively little interference with the ongoing process of comprehension.

This dissertation describes how the influence of the verb on both the structure
(Chapter 4) and the meaning (Chapter 5) of a sentence affects its activation pattern. Before
presenting data on the on-line involvement of verbs with other sentential material, a
language-specific characteristic of verbs in the type of Dutch sentences used here (i.e., verb
movement) is discussed in Chapter 3.
Whereas the activation pattern of the matrix verb from its first appearance until the end of its clause (the main clause) is described in Chapters 3-5, Chapter 6 takes one step further: in this chapter the influence of the matrix verb during the embedded clause following is discussed.

The experimental chapters are preceded by a thorough discussion of the CMLP paradigm (Chapter 2) and followed by a general discussion (Chapter 7).