Sound-spelling units in German word identification

A developmental perspective

Kumulative Dissertation

zur Erlangung des Doktorgrades (Dr. phil.)

durch die Humanwissenschaftliche Fakultät

der Universität zu Köln

Gutachter*innen:

Prof. Dr. Martina Penke

Prof. Dr. Alfred Schabmann

vorgelegt von

Sandra Beyermann

aus Berlin

2015

Disputation: 09.03.2016

Theoretical Background

Empirical Studies

*****Full titles of published articles for this dissertation project:

Study 1: Beyermann, S. & M. Penke (2014b). Word stress in German single-word reading. *Reading Psychology*, 35(6), 577-600. [To cite this article: Beyermann, S. & M. Penke (2014). Word Stress in German Single-Word Reading, *Reading Psychology*, DOI 10.1080/02702711.2013.790325]

Study 2: Beyermann, S. (2013). Orthographic cues to word stress in German: Word endings and number of final consonant letters. *Written Language and Literacy*, 16(1), 32-59. DOI: 10.1075/wll.16.1.02bey

Study 3: Beyermann, S. & M. Penke (2014a). The impact of orthographic consistency on German spoken word identification. *International Journal of Disability, Development and Education*, 61(3), 212-224. DOI: 10.1080/1034912X.2014.932564

1. Introduction and overview

The first archeological evidence for the invention of a writing system is approximated for the 4th millennium BC (e.g., Olson 1993:4) and considered as a mile stone in the human history. By means of a script, i.e., an inventory of graphic signs, information can be systematically preserved by writing it down. Thus, the invention of a writing system provided a new instrument to represent and conserve knowledge and transfer it across space and time. Writing is a cultural achievement, a technical innovation *"shaped by civilization and a tool shaping it"* (Coulmas 1989:4). Complex societies which include forms of industry, commerce, administration, science, technology and art usually develop forms of writing (Coulmas 1989:7).

Learning to read written language opens the world – proficient readers can in principle learn everything that is written down – ranging from time tables, receipts or short messages to complex texts, for example about scientific observations and theories. In this sense reading acquisition is an essential basis for educational achievements. Hot debates on the results of recent international reading assessment programs (for example PISA, see e.g., Naumann, Artelt, Schneider & Stanat 2010) emphasize the importance of reading proficiency for the educational development of individual students. Studies in the field of reading research may contribute to a better understanding of the skills underlying reading and the way they are achieved. Reading is a cognitive process that provides information through the visual representation of language units, and these visual units, basically printed single words, need to be identified to build up mental representations of the language units (Perfetti 2001). Thus, the identification of written words can be viewed as a basic operation in the reading process.

Written language conveys information by means of a graphic representation of language (e.g., Sampson 1985). In languages with an alphabetic writing system like German, Dutch, English or French letters have a phonographic function, i.e., letters and letter groups represent sound units of the language, or, in other words, graphemes represent phonemes. For example, in German the single letter <t> expresses the phoneme /t/, and the multi-letter string <sch> expresses the phoneme /ʃ/, e.g., <*Tisch*>, /tɪʃ/ 'table'. Thus, the meaning of written words can be decoded by mapping printed units to sound units of the language (and blending the given sound units to form the spoken word in order to retrieve its meaning from memory). This print-to-sound translation is called phonological recoding. Acquiring knowledge about systematic letter-sound correspondences, i.e., about the alphabetic principle, is a crucial step in reading acquisition (see Chapter 2.3). The view that phonological recoding skills are essential in reading acquisition is widely accepted in the literature (e.g., Jorm & Share 1983). In early stages of reading acquisition, beginning readers identify printed words predominantly via phonological recoding strategies (Ehri 1992, Share 1995, Frith, Wimmer & Landerl 1998). It is often assumed that due to print exposure and growing experience in word reading, a number of words can be identified by sight (sight words), i.e., without segmenting the word into spelling units, and translating spelling units to sound units. This word identification strategy is considered a pure orthographic or direct processing route from written words to stored word knowledge in the mental lexicon. So-called dual-route models of reading (e.g., Coltheart, Curtis, Atkins & Haller 1993; Coltheart, Rastle, Perry, Langdon, & Ziegler 2001; Perry, Ziegler & Zorzi 2007, 2010) capture these two different routes, i.e., the phonological and the orthographic route, as separate word identification mechanisms which both develop during reading acquisition.[1] According to dual route models, knowledge about word forms (phonological, orthographic, as well as semantic information) is stored in the mental lexicon. When a skilled reader recognizes a printed word, the corresponding lexical entry is addressed and the stored information about a word's spelling, pronunciation and meaning can be retrieved. It is obvious that the pre-literate children's lexical knowledge on word forms lacks orthographic information and thus, differs from that of literate speakers. While learning to read the beginning readers memorize implicit information about words by the repeated identification of spelling patterns as specific words (e.g., Klicpera, Schabmann & Gasteiger-Klicpera 2010: 104f; Share 1995). A reader might implicitly learn the correct spelling pattern for a word after recognizing it for several times (e.g., Klicpera et al. 2010:104f). In other words, by gaining reading experience during education the quality and quantity of the individual orthographic knowledge constantly increases.

Many proponents of the dual-route theories of reading assume that in advanced stages of reading development, the initially predominant phonological recoding procedure is successively substituted with orthographic processing mechanisms that allow for a direct and faster mapping of letter strings to word meanings (e.g., Sprenger-Charolles, Siegel, Béchennec, & Serniclaes 2003; Bijeljac-Babic, Millogo, Farioli, & Grainger 2004; Coltheart & Rastle 1994). In other words, a skilled reader does not necessarily need to activate phonological information in order to identify a familiar word from print. This

[1] There are alternative reading models (e.g., Seidenberg & McClelland 1989; Plaut, McClelland, Seidenberg & Patterson 1996) which also successfully simulate many of the typical behavioral patterns in word reading; compare e.g., Perry, Ziegler & Zorzi 2007).

assumption is for example supported by observations of regularity effects in skilled readers reported by Taft & van Graan (1998). A word is seen as orthographically regular if its pronunciation can be inferred from print-to-sound translation rules that apply regularly for a number of words; e.g., VINE, sharing the pronunciation of the rime with e.g., *line, fine*. In contrast, the pronunciation of irregular words deviates from spelling-sound translation rules; e.g., VASE differing from e.g., *phase*, *base*. Regularity effects in visual word processing like those reported in Taft & van Graan are assumed to arise from the interaction between phonological and orthographic information which are linked to each other in the reading system. In their study, Taft & van Graan reported that the same set of target words that lead to significant regularity effects in a naming task (reflected in faster and more accurate performances in naming VINE vs. VASE) did not produce a regularity effect when subsequently employed as stimulus material in a semantic categorization task with skilled readers of English. The absence of a regularity effect in the semantic decision data indicates that the participants' performances in this silent reading task were based on orthographic rather than phonological information (Taft & van Graan, 1998). If phonological information was automatically addressed the regularity effect should have been observed for both the naming and the semantic categorization task. Taft & van Graan conclude from their findings that phonology is not necessarily involved in the access to word meanings; though it might be automatically activated to support the working memory with additional information (Baddeley, Eldridge & Lewis 1981).

The automatic processing of phonology during unimpaired skilled reading has for example been addressed by experiments on the processing of homophonous words and pseudowords in text reading (e.g., Pollatsek, Lesch, Morris & Rayner 1992; Inhoff & Topolski 1994; Daneman & Reingold 1993, 2000 on English), or in silent single-word reading employing homophonous stimulus material (e.g., Van Orden 1987 on English; or Ziegler, Jacobs & Klüppel 2001; Penke & Schrader 2008 on German). For example Ziegler et al. (2001) compared the lexical decision performances of German skilled readers when presented with written pseudohomophones [2] (e.g., SAHL derived from SAAL "hall, saloon") and spelling controls (e.g., SARL derived from SAAL). The participants were significantly slower and less accurate in rejecting homophonous non-words than in rejecting spelling controls. In other words, pseudowords sharing the same phonological form with an existing word (e.g., SAHL) were harder to identify as non-words than spelling controls (SARL). This observation implies that the participants automatically

[2] Pseudohomophones are nonsense words that sound like real words.

activated phonological information although the actual reading task (judging the lexical status of given letter strings as words or non-words) could be accomplished on the basis of orthographic information alone. The robustness of such phonological effects during reading observed in a variety of experimental tasks (see e.g., Frost 1998) supports the view of an automatic activation of the phonological component during reading which is widely accepted in the literature (e.g., Coltheart et al. 2001:212; Perfetti 2011; Rapp, Folk & Tainturier, 2000). In other words, there is a broad consensus on the assumption that phonological and orthographic processing routines are both activated in parallel during word reading. But note that the controversy among scholars also concerns the issue whether the phonological or the orthographic route is dominant in skilled word reading, or in other words, whether orthographic or phonological codes are activated earlier during word identification, and whether orthographic or phonological information is crucial for semantic access.[3] However, this debate is beyond the scope of the present work which follows the assumption that phonology is automatically activated in the word identification process in alphabetic languages (see Chapter 2).

Phonology shapes word reading units

Cross-language studies provide empirical support for the assumption that the relevance of functional units in word reading varies as a function of language. In other words, reading in different languages might involve different processing units, which needs to be considered in theoretical accounts on word reading (e.g., Frost 2012; Ziegler & Goswami 2005).

Whereas numerous studies have demonstrated phonological effects in reading the question which units of phonological representation are processed has been disregarded for a long time. Note that written language is always underspecified with respect to some aspects of spoken language (such as stress, intonation, speech pause). Prosodic properties are not explicitly encoded in written language. However, the role of prosodic units during reading has recently come more into the focus of a number of studies (e.g., Colombo 1991; Colombo & Tabossi 1992 on Italian; Kelly, Morris & Verrekia 1998; Rastle & Coltheart

[3] Given that the phonological or non-lexical route was predominant in visual word identification, it might even be the case that the retrieval of phonological information is mandatory for the access to word meanings (i.e., the access to word meanings is phonologically mediated). See e.g., Rapp, Folk & Tainturier (2000:242ff) for a discussion of psycholinguistic and neuropsychological evidence. Recently, neurophysiological and neuroimaging studies contribute to this controversial issue; see e.g., Grainger, Kiyonaga & Holcomb (2006).

2000; Ashby & Clifton 2005 on English). Especially when considering polysyllabic words or sentence and text reading, it is worth questioning whether supra-segmental units are involved. A strong claim towards the automatic processing of prosodic properties was made by Fodor (1998, 2002; see also Black & Byng 1986) in her *Implicit Prosody Hypothesis* on stress languages. The hypothesis claims that during silent reading a default prosodic contour is automatically imposed on the visual input. The default prosodic structure is the most natural structure for the given input, and the assignment of the default structure might influence the resolution of ambiguous sentences (for example the ambiguous attachment of the relative clause in sentences like *He hit* [*the companion*]$_{NP1}$ *of* [*the police officer*]$_{NP2}$ [*who was found dead*]$_{RC}$).[4] However, the Implicit Prosody Hypothesis does not presuppose that lexical stress, i.e., word-level prosody, is automatically assigned to single words during reading (cf. Ashby 2006). It might as well be that during silent reading only phrase and sentence level prosody is imposed on basic units (compare e.g., Frost 1998). Hence, more needs to be learnt about the role of prosody during word identification in the reading process.

As a result of the anglo-centricity in reading research (Share, 2008) a large proportion of the studies concerned with the impact of phonology on visual word processing are focused on English. But note that many languages are substantially different from English e.g., with respect to morpho-syntactic or phonological factors (e.g., Japanese, Chinese), or with respect to orthographic transparency and consistency (e.g., Spanish, German, Dutch). Cross-language investigations have demonstrated differences in word reading performances in different stages of reading development (e.g., Aro & Wimmer 2003; Seymour, Aro & Erskine 2003), and in skilled readers (e.g., with respect to the word length effect, see Ziegler, Perry, Jacobs & Braun, 2001; or the transposed letter effect; e.g., Frost 2012). As a consequence, findings from reading research on English cannot be directly transferred to other languages. A large number of studies providing the empirical basis for theoretical approaches on word reading were only focused on English. This lack of cross-linguistic evidence calls for a broader empirical basis considering languages other than English with its extreme orthography (compare Chapter 2.1.2). Therefore, the present work is concerned with visual word processing in German that has a more regular orthography in terms of spelling-to-sound correspondences (e.g., Borgwaldt, Hellwig & de Groot, 2004), and has been subject to fewer empirical investigations (e.g., Penke & Schrader 2008).

[4] For English, an attachment of the relative clause to the lower NP [the police officer] is seen as the preferred structure, which relates to the absence of a phrase boundary before the relative clause as the default (Jun 2003).

This cumulative dissertation comprises of a theoretical part (Chapter 2 to 3), and an empirical part (Chapter 4 to 6) which is based upon three published articles (Beyermann & Penke 2014a, and b; Beyermann 2013). Part of this work was supported by grant G.0292.09N from FWO (Fonds Wetenschappelijk Onderzoek, Vlaanderen) to my supervisor Martina Penke.

The present work is concerned with some questions on how literacy acquisition changes the way words are processed. More specifically, this dissertation aims to contribute to a broader knowledge about the interaction of phonology and orthography in German word processing. First, Chapter 2 provides the theoretical background of the central empirical objective pursued by the present work. Chapter 2.1 gives an overview of language-specific properties that impact on the word reading system, thus explaining the inducement to investigate word reading in a language other than English (here German) and giving an outline of the German writing system and orthography. However, differences in how written words are processed were not only found present across different languages, but also across readers at different stages of reading development. Therefore, Chapter 2.2 gives a short description of unimpaired reading acquisition (in German). The subsequent Chapter 3 outlines the aims of this dissertation. The central questions are:

1. Do supra-segmental phonological units (exemplified on word stress) constitute processing units in German word reading? And does the functional relevance of these units vary as a function of reading experience?

2. Do spelling patterns of German words provide potential cues to word stress?

3. Does orthography (spelling knowledge) influence spoken word processing? And does the influence of spelling knowledge on spoken word processing vary as a function of reading experience?

For one, the present study aims at contributing to a broader knowledge about the issue of phonological activation in the reading process. More precisely, it focuses on the question whether word stress[5], a prosodic feature is involved in German word reading at different stages of reading development.

[5] Word stress, which is phonetically encoded by modulations of the fundamental frequency (f_0), duration and intensity of stressed elements, expresses an abstract prominence relation between syllables in a word (e.g., Liberman & Prince 1977), and groups syllables in a word into metrical units. Metrical information from the word-level is a basis for the higher-level prosodic organization that affects the syntactic and semantic interpretation of utterances.

Two articles were devoted to this question (Beyermann & Penke 2014b, Study 1 in Chapter 4; and Beyermann 2013, Study 2 in Chapter 5; a study completed subsequently to study 1, but published earlier). In short, the first and major part of this dissertation (Chapter 4 and 5) investigates the question whether prosodic units (patterns of word stress) which are not marked explicitly in written words are activated during German word reading, and whether orthographic patterns might provide implicit cues to word stress.

However, the impact of phonology on visual word processing is only half the story when considering the link between units of spoken and written language. In unimpaired first language acquisition, the perception and production of language is usually confined to its spoken form for several years. Learning to read seems to change the way we perceive spoken language. The second part of this dissertation (Study 3 in Chapter 6) briefly presents a third published article: Beyermann & Penke (2014a) investigating whether units of written language (spelling patterns) are involved in auditory word processing. It is reasoned that orthographic effects in auditory processing might arise from a supportive function of spelling knowledge for the working memory (Taft 2011). This would be analogous to an automatic phonological activation during word reading which supports the working memory with additional information on the input (compare previous section; Baddeley et al. 1981). In other words, both parts of the present work allude to the more general question about which spelling-sound units are activated during word processing, either in the written or spoken modality. Finally, Chapter 7 discusses the outcomes of the presented studies with respect to theoretical assumptions on word reading and reading acquisition.

2. Reading and reading acquisition

The present chapter first introduces important aspects of the assumed cognitive word reading system which are influenced by language-specific factors (Chapter 2.1). The subsequent Chapter 2.2 is concerned with the development of the reading system focusing on German.

Written languages may differ with respect to *a) their scripts*, i.e., the inventory of functional graphical elements, compare e.g., the Roman vs. Cyrillic script in French vs. Russian; *b) their writing system*, i.e., which language units are represented by basic units of writing, compare e.g. logographic systems like Chinese where graphic symbols represent morpho-syllabic units vs. alphabetic systems like German where graphic symbols represent phonemic units; and *c) their orthography*, i.e., writing principles, determining e.g., grapheme translations, word spellings, or punctuation (compare Perfetti 2003).

For example Perfetti & Dunlap (2008) emphasize the influence of the writing system and orthography of a language on literacy acquisition. Such linguistic differences can be associated with differences in the development and impairment of word reading processes across languages (e.g., Landerl, Wimmer & Frith 1997; Perfetti & Liu, 2005; Yoon, Bolger, Kwon, & Perfetti 2002; Ziegler & Goswami 2005). In other words, the cognitive reading system of readers adapts to language-specific properties (see e.g., Frost 2012; Wang, Koda & Perfetti 2004; Perfetti, Cao, & Booth 2013 for empirical evidence), and, what has been found for English reading and reading development does not necessarily hold for other languages.

2.1 Language-specific vs. universal properties of the reading system

What is common to the reading process in different languages? Reading is a highly complex mental information processing activity (Coltheart 2006) that is based on a specialized system of component processes (from letter to word identification, sentence and text comprehension). Reading across all writing systems aims to extract meaning from print, and word decoding is considered a basic foundation skill of reading (e.g., Stanovich 1982, Gough & Tunmer 1986; Hoover & Gough 1990; Balota 1994; Joshi & Aaron 2000). Common to all languages with any writing system is that written language encodes the spoken language. When children learn to read they learn how language units are encoded in units of the written language (e.g., Perfetti & Dunlap 2008). Because the identification of single printed words is an essential component process of reading, a great deal of empirical and theoretical investigations focused on single word identification. Word identification is the process in which a given visual or auditory signal is detected as identical to a word form stored in memory requiring lexical access (to long-term memory, where information on word forms is stored) which might be attended by semantic access (to the word meaning stored in memory). A decoded or identified written word unit – both terms decoding and identification are used as synonyms here – may be subject to further processing (e.g., spelling out). According to the *Lexical Constituency Model* (Perfetti & Liu 2006) word identification is associated with the access to stored lexical information on that word (spelling information, pronunciation, word meaning). These components of lexical information are assumed to be highly interlocked in proficient readers, whereas they are less specific and less connected in younger or less skilled readers (e.g., Landerl, Frith & Wimmer 1996; see also Chapter 2.3). Cross-language differences in linguistic structure (phonology, morphology), writing systems and orthographic systems can be associated with differences in the relative importance of single lexical components (Perfetti 2011:161) and their involvement during word reading (see next chapter).

2.1.1 Writing systems

For a large number among approximately 3000 different spoken languages in the world (Frost 2012:266) a diversity of visual codes have evolved which may differ in script type, writing system or orthography. Common to all written languages is that the basic units of written sentences are written words, and that written language conveys meaning by representing morphemic information (Hung & Tzeng 1981; Frost 2012). The cross-language differences emerge from different coding systems (writing and orthographic system) and they affect the lower input level: Readers in different languages are confronted with different ways printed words express language units.[6]

[6] The script type is not considered an important factor for cross-language differences in the reading system (Perfetti & Dunlap 2008).

Broadly speaking, writing systems are traditionally determined by the basic language unit corresponding to a single graphical unit (phonemes, syllables, or morphemes)[7]. Thus, writing systems are classified as alphabetic systems (e.g., English, German, and Hebrew where graphemes refer to phonemes), syllabic systems (where graphemes represent syllables; e.g., Japanese Kana, see Perfetti & Dunlap 2008) or logographic systems (characters refer to syllabic morphemes, e.g., Chinese, see Wang, Cheng & Chen 2006).

According to Frost (2012) the evolution of a certain writing system for a language complies with the linguistic properties of that language. Take as an example the logographic system of the Chinese languages. The Chinese printed characters often combine a semantic radical with a phonetic radical to refer to a lexical morphemic unit; e.g., 燈 /dang/1 "lamp" combines the semantic radical **火** for "fire" with the phonetic radical 登 /dang/1 "climb" resulting in an ideophonic compound (Ho & Bryant 1997; see also Huang & Hanley 1994)[8]. Chinese languages are classified as analytical in the sense that grammatical relations among words in a sentence are expressed by function words or word order rather than affixation (e.g., Bußmann 2002). This means that single words are usually monomorphemic. Moreover, complex onsets or codas are not allowed; thus, single words in Chinese are usually short (one syllable) and have a simple phonological structure. Due to the restrictions in the number and structure of syllables that constitute words — the syllable inventory of Chinese is relatively small (about 400 syllables; e.g., Cholin, Levelt & Schiller 2006)[9] — the phonological space of Chinese is rather dense, i.e., a small number of different phonological forms maps to a large number of different meanings, leading to many cases of homophony (Frost 2012). In speech, the correct meaning of a phonological word form (as intended by the speaker) can often be identified by different tone contours which have a lexically distinctive function in Chinese. But tones are not explicitly represented in written Chinese. However, for example the combination of different semantic radicals with the same phonetic radical allows a distinction between different word meanings, e.g., as is the case for the spoken syllable /dang/1 which is

[7] A ***phoneme*** can be defined as the smallest lexically distinctive unit in spoken language (compare e.g., *look* vs. *cook*). ***Syllables*** are the basic articulatory units of spoken language, and thus subject to typical phonological processes on the segmental level (e.g., feature assimilation), and on the supra-segmental, prosodic level (word stress, sentence accent, intonation). Syllables are comprised of a nucleus (obligatory), a coda (optional), and an onset (optional), and the nucleus and coda form the syllable rime. Languages differ with respect to the inventory of syllable structures (for more details, see e.g., Kenstowicz 1994). ***Morphemes*** are the smallest units of meaning (either grammatical like *the*, or lexical like *house*), cf. Bußmann (2002).

[8] In the example /dang/1, the tone number '1' denotes a high level tone (see Ho & Bryant 1997).

[9] Note that this count does not consider tones; if tone contours are considered as part of syllables, the total set contains approximately 1200 different syllables; Chen, Chen & Dell (2002).

expressed by the phonetic radical 登, and to mean the word 燈 “lamp” it is designated by the semantic radical 火 for “fire” (compare Ho & Bryant 1997). In contrast to learning to read in alphabetic languages, where learning letter-sound or grapheme-phoneme correspondences is an essential first step, Chinese reading acquisition is assumed to be based on learning a large number of grapheme-morpheme relations (Wang et al. 2006). According to Perfetti & Dunlap (2008:34) Chinese is *“a poor candidate for an alphabet because of its many homophones and its tone system.”* In other words, the Chinese logographic system is well adapted to the dense phonological space of the language, providing the reader with signals that directly map to the semantic meaning in order to identify printed words (Frost 2012).

Compare the logographic system of Chinese for example with English and Hebrew, two alphabetic systems. In English, spelling units of the word refer to vocalic and consonantal segments (e.g., in *flush*, the graphemes <f>, <l>, <u>, <sh> correspond to the phonemes /f/, /l/, /ʌ/, /ʃ/, which can be assembled to form the spoken word /flʌʃ/), whereas in Hebrew graphemes usually refer to consonants, and vowels are often not represented in print. In other words, written Hebrew differs from English in that it employs a consonantal script. What might be the linguistic difference underlying the evolution of different alphabetic systems for English vs. Hebrew? According to Frost (2012) cross-language differences in the structure of the phonological space as well as differences in the representation of morphemes and meaning by phonological units might have evoked the development of the differences in their writing systems.

Hebrew content words are usually root derived, i.e., word forms are based on one out of 3000 different root morphemes which expresses the core meaning; e.g., זמר /ZMR/ representing the concept ‘singing’. More precisely, Hebrew printed words are composed of the root morpheme (usually a skeleton containing three root consonants) which is embedded in a word pattern expressing morphological properties (there are about 100 different morphological word patterns which appear as a set of restricted phonological forms containing slots for the root segments). Hebrew inflection is thus different from English and German in that morphemes are not always combined in a linear order but they are intertwined.[10] For example, the written word תזמורת[11] /tizmoret/ ‘orchestra’ is based on the root morpheme /ZMR/ combined with the word pattern /ti-o-et/ which refers to a class of feminine nouns (for more details see Frost, Forster & Deutsch 1997; Shimron 1993;

[10] Some morphological operations are realized by linear affixation (see e.g., Schiff & Ravid 2004).
[11] Note that words in the Semitic language Hebrew (like Arabic) are written and read from right to left.

Frost 2012). The root consonants may appear in different positions throughout different word patterns, but the linear order is the same across different word forms derived from the same root morpheme. Roots are highly distinctive elements constituting words, and the identification of the root is essential to extract the core meaning of printed words.

Written Hebrew employs 22 letters and optionally additional diacritic vowel marks (pointed Hebrew is usually restricted to certain contexts, e.g., text materials for beginning readers). The consonantal script with a rather small number of letters is well-suited to represent words in Hebrew; it provides the reader with the essential semantic information to quickly identify the word's base (Frost 2012; Shimron 1993). On the one hand, written words in Hebrew contain impoverished but sufficient phonological cues to identify the word pattern (e.g., in /tizmoret/ the initial letter for /t/ considerably reduces the set of possible subsequent segments in the word pattern /ti-o-et/; Frost 2012). On the other hand, the letters constituting the root morpheme are more prominent and thus can be quickly identified due to the lack of vocalic information predictable from the word pattern (in the given example, /i/ and /e/ are not represented). The salience of the root consonants embedded in a rather small set of invariant word patterns (which appear frequently in different words) makes it relatively easy to segregate the word's basis and affixes, identify the relevant root morpheme and the core meaning. If Hebrew would be printed in a full-alphabetic system including vowel letters this would probably decrease the visibility of the root letters, because then a larger inventory of different letters could appear in different positions between the root letters. Moreover, including all the vowels in the orthographic representations would contribute additional, but rather predictable grammatical information, since the vowels are lexically less informative in Hebrew (Shimron 1993). In sum, although the phonemically underspecified orthographic representations might impede the phonological decoding of printed words, the consonantal system is well-suited for representing language units that convey meaning in Hebrew.

Would such a consonantal system be a good system for English? Why are there vowel letters in English? Note that shorthand systems in any language usually shorten written words by reducing vowel letters (Shimron 1993). Moreover, skilled readers of English performed well in reconstructing texts from which all vowel letters and the spaces were removed (Miller & Friedman 1957). This might lead to the assumption that English orthography could as well be based on a consonantal script. Shimron (1993) noted that for one, English has a comparatively rich inventory of vowel phonemes (about 22 vowels; compare this to five basic vowels in Hebrew phonology). Moreover, vowel tenseness is not lexically distinctive in Hebrew but it can be distinctive in English (compare e.g., /ɪ/ vs. /i/ in *slip* vs. *sleep*; see e.g., Giegerich 1992:98; Hammond 1997; Shimron 1993). In the light of the relatively rich English vowel system it seems that leaving out vocalic information would cause a high degree of uncertainty about the phonemic content in printed words; simply because this would generate many potentially alternative pronunciations. Furthermore, in contrast to Hebrew, where most words are composed of CV or CVC syllables, although some complex syllable margins are allowed (CCVC and CVCC structures, Shimron 1993; Share & Blum 2005), English words often contain complex syllable margins (e.g., *twinkle, offspring*), i.e., the phonological space is quite complex, with several thousand different syllables (approximately 8000; e.g., Frost 2012:269). It is conceivable that grouping letters in syllable units reduces the number of processing units to be hold in memory, and thus facilitates word identification (compare Treiman & Zukowski 1990; Shimron 1993). In languages with many complex syllable structures like English, consonant clusters might represent complex syllable margins as well as polysyllabic structures (compare e.g., <thrgh> corresponding to *thorough* and *through*). Lacking vowel information turns the number of syllables and the syllable structure less visible, rendering word spellings ambiguous (homographic) and making it hard to distinguish different meanings without external cues like the semantic context (compare e.g., more than 10 different words and different word meanings would be represented by the letters <brn>, e.g., *auburn, barn, baron, brain, bran, brine, boron, born, borne, Iberian*). Including vowel information in English printed words specifies their phonemic content and might thus facilitate the phonological decoding. But above that, the vowel graphemes have another important function. In English a shared morphological origin of related words (derived from the same stem) is often obscured by phonological variation, e.g. by inflection in *hear – heard* or derivation *heal – health (*e.g., Frost 2012). This phonological variation across related words is due to the fact that the English vocabulary contains many words from different languages with different phonologies (Perfetti & Dunlap 2008), and that the pronunciation of words has undergone many diachronic changes which were not captured by changes in the spelling (see Seidenberg 1985). A constant spelling pattern for words of the same morphological origin enhances the visibility of their morpho-semantic relation. This orthographic principle is called morpheme constancy (e.g., Scheerer 1987; Bourassa & Treiman 2008). Both vowel and consonant letters are assumed to contribute to the identification of the word, i.e., consonant and vowel letters have about the same diagnostic value in English single word reading (Frost 2012)[12]. In contrast to English,

[12] Note for example that English homophones can be distinguished by different vowel spellings (e.g., *brake*

many homographs in Hebrew share the same morphological origin, and thus express a similar semantic content. Shimron (1993) points out that the structure of Hebrew words in the consonantal script is actually leading to a high degree of visual similarity between morphologically related words which are derived from the same root morpheme. The morphological structure of Hebrew words favors a consonantal script that increases the visibility of the morphological basis. Thus, differences in the phonological and orthographic structure might have favored a full-alphabetic system to evolve for English, but not for Hebrew.[13]

In sum, the expression of morphological information is central to writing systems (see e.g., Katz & Frost 2001). According to Frost (2012), in any writing system the representation of the morphological origin takes precedence over providing phonological information which might facilitate the phonological recoding of printed words. Frost suggests that the development of different writing systems approximates an optimal orthographic structure that represents relevant linguistic units (that convey meaning) with minimal orthographic units. The comparison of Hebrew and English complies with this assumption.

Differences in neuronal activities across writing systems

One the one hand, writing systems are adapted to structural properties of the spoken language they represent. On the other hand, empirical evidence demonstrates that the brain network underlying the reading system accommodates to the peculiarities of the writing system (the *System Accommodation Hypothesis*; Perfetti & Liu 2005). A series of cross-language neurophysiological studies on English vs. Chinese have demonstrated that some shared brain regions, as well as some different brain regions are activated when readers process written words in different writing systems (see Perfetti & Dunlap 2008, and references cited therein). From these observations it might be concluded that some mechanisms of the reading system are universal across different languages. Perfetti & Dunlap suggest that the visual analysis of graphical units always precedes the orthographic,

vs. *break*). However, according to Cutler (2005) homophones which are distinguished by different spellings are rare in the English vocabulary. Cutler identified about 700 homophones (such as *meat* vs. *meet*, or *brake* vs. *break*) in the list of 70.000 English word forms in CELEX; thus, in contrast to Chinese readers, one might assume that the distinction of homophones is a rather residual problem for English readers.

[13] School children are introduced to a pointed version of Hebrew when learning to read; in this form of written Hebrew the usually missing vowels are marked by diacritics. Skilled readers thus are able to read pointed and unpointed Hebrew (Shimron 1993).

semantic and phonological processing, and that the operational principles of these component processes might be the same across languages. However, the observation that some different brain regions were involved when reading in English vs. Chinese indicates that the skilled reading system is adapted to language-specific properties of print.

In the course of reading acquisition, a reader acquires automatic processing routines for visual word identification. According to Frost (2012) these processing routines are adapted to the system of information representation in the corresponding written language. The previous section briefly illustrated that the lexical architecture of a language (i.e., the phonological and morpho-syntactic structure of words) shapes the informational content expressed by a spelling unit of that language (e.g., Frost 2012). The writing system and orthographic factors determine the shape and contribute to the functional relevance of perceptual reading units. The observations made by cross-language investigations suggest that on the one hand, these language-specific factors influence the evolution of a writing system, and on the other hand, the reading system (i.e., the neural network and the cognitive operations involved in reading) is fine-tuned to features of the written language.

The German writing system

Like English, German is written in an alphabetic system in which letters and functional letter groups represent vowel or consonant phonemes. In other words, the spelling units in German directly refer to arbitrary, but lexically distinctive sound units of spoken language. In contrast to Chinese or Hebrew, German orthography directly provides the reader with relatively specific phonemic representations of words (i.e., with a sequence of letters representing a sequence of phonemes).

The task of reading German and English is similar in many respects. For one, the phonological space of both languages is rather complex. German words are composed of more than 6000 different syllables with less than 30% of them having a simple structure like CV or CVC (Conrad & Jacobs, 2004). Like in English, syllables in German may contain consonant clusters in the onset and in the coda position (e.g., *Strumpf* /ʃtRʊmp^{f}/ ‘sock, stocking’), and German has a large vowel inventory (16 vowels and three diphthongs, see e.g., Dieling & Hirschfeld 2002).[14] In other words, German words are constituted by a wide range of different syllable structures (compare e.g., *Hose* /ho.zə/

[14] Like in English, vowel tenseness is lexically distinctive; compare e.g., *Kehle* with a tense vowel /ke:lə/ ‘throat, gorge’ vs. *Kelle* /kɛlə/ with a lax vowel ‘dipper, ladle’; e.g., Jessen (1993).

'trousers' vs. *Strumpf* /ʃtχʊmp^f/ 'sock, stocking'). The phonemic principle of the German orthography, i.e., that the phonemes constituting a word are represented by a grapheme in the printed word, provides the reader with detailed information on the phonemic structure of that word.

However, in a recent study by Marian, Bartolotti, Chabal & Shook (2012) it was demonstrated that the phonological space is less dense in German as compared to English, i.e., German words tend to have fewer phonological neighbors than English words (the same is true for the mean number of orthographic neighbors). This difference between German and English might influence visual word processing, but to my knowledge this issue has not yet been addressed by empirical studies and thus can only be a matter of speculation. But the overriding difference between written English and German lies in properties of the orthographic system. The subsequent chapter sketches these differences and thus emphasizes the need for more empirical investigations of languages other than English.

2.1.2 Orthographies

Compared to a small number of languages employing a logographic writing system (Chinese, and written languages that incorporated the Chinese system, i.e., Japanese Kanji and Korean Hanza) there is a variety of different syllabic systems and alphabetic systems. Across the alphabetic languages the orthographic systems (i.e., the principles of letter-phoneme correspondences, spelling, punctuation, and capitalization) can be very different from another. In general, orthographic systems of alphabetic languages can be classified as predominantly phonemic or morphophonemic. In a phonemic system, word spellings usually reflect the pronunciation of the word unambiguously (the spelling-sound relations are highly transparent because spelling pattern regularly translate to patterns of pronunciation), whereas in morphophonemic systems the unambiguous expression of morphological relations takes precedence over the unambiguous expression of phonemic content, and the spelling-sound relations are less transparent. Compare for example the orthographies of both alphabetic languages English (morphophonemic) and Dutch (phonemic). Both orthographies differ in terms of the transparency of spelling-sound relations in printed words as well as with respect to the spelling variability across words with a shared morphological basis.

In Dutch, for example the quality and quantity of stressed vowels is usually marked unambiguously by the vowel grapheme and the orthographic syllable structure, e.g. <o> in an open syllable marks a tense /o/, like in *lopen* 'to walk'; whereas <o> in a closed syllable signals a lax /ɔ/, like in *stoppen* 'to stop, stuff' (see e.g., Gussenhoven 1992). In contrast to that, English vowel spellings do not systematically express vowel tenseness (e.g., *balm* pronounced with a tense /ɑ/ vs. *bomb* pronounced with a lax /ɔ/). The same vowel spelling might even correspond to different vowel phonemes, compare e.g. <o> in *sword* vs. *word*. Beyond that, the same vowel phoneme in English is represented by different spelling patterns; compare e.g. the same vowel in *bird*, *word, heard*. These inconsistencies in the spelling-sound relations mainly arise because of the principle of morpheme constancy which applies in the English orthography and the phonological variability of related words in English (see previous chapter; cf. Frost 2012). A constant spelling pattern in words of the same morphological origin expresses their morpho-semantic relation; e.g. in *heal* and *health*. There is considerable phonological variation in morphologically related words in English (compare e.g., a different pronunciation of the plural morpheme –s in *bugs* vs. *books,* or the vowel in *to learn* (infinite) and *she/he learnt* vs. *to hear* and *she/he heard*). The same morpheme might correspond to different pronunciations but it is usually spelled the same across different morphologically related words. As a consequence, the English orthography contains many ambiguous sound-to-spelling correspondences (e.g. the vowel phoneme /i/ can be represented by different graphemes <ee> in *sheep*, <ea> in *hear*, <e_e> in *here*), and spelling-to-sound correspondences (e.g., <ea> might represent /i/ or /ɛ/, compare *hear* vs. *bear*). In other words, the phonemic inconsistencies are the price to pay for a constant spelling pattern of morphologically related words in English.

In contrast to that, the pronunciations of written words in Dutch are usually unambiguously predictable from the spelling (e.g., *lopen* vs. *stoppen*), and the correct spelling can usually be inferred from the sound. But the phonemic faithfulness, i.e., the high degree of transparency in spelling-to-sound and sound-to-spelling translations sometimes conceals the morphological relation of words (compare e.g., *bellen* (infinite) vs. *hij/zij belde* 'to call, she/he calls' or the same morphological origin in *wonen* (infinite), *zij/hij woont*, *gewoon* 'to live/to reside, she/he lives/resides, usually/customary').

In German, like in English, the conventional spelling patterns of words obey the principle of morpheme constancy, i.e., a shared morphological stem is usually spelled the same in different words (compare e.g., *Hund* /hʊnt/ 'dog (Singular)', *Hunde* /hʊndə/ 'dogs (Plural)'). In other words, the German orthographic system is morphophonemic in the sense that it expresses a shared morphological origin by means of constant spelling patterns over related words. However, the German orthography is more transparent than the English orthography (Borgwaldt et al. 2004), and this might be partially due to more consistent pronunciations of morphologically related words in German compared to English (compare Frost & Katz 1992). The next section gives a brief overview of the empirical findings underlying the view that such a difference in the degree of orthographic transparency is responsible for differences in the reading system.

Orthographic transparency

The transparency of sound-spelling relations and the spelling constancy of related words may vary dramatically across different languages. Note that, in the literature the term consistency is applied for different aspects of spelling-sound mappings: First, the overall degree of transparency in an orthographic system can be categorized by determining the consistency in the spelling-to-sound translations (e.g., <p> in English printed words refers to the phoneme /p/), and the sound-to-spelling translations (e.g., the phoneme /p/ is represented by <p>); see e.g., Borgwaldt et al. (2004). Orthographies with mainly unambiguous letter-phoneme relations are classified as transparent (such as Dutch, Finnish, or, to a lesser degree, German), whereas orthographies with many ambiguous letter-phoneme correspondences are less transparent (e.g., English, Danish). The orthographic transparency was shown to influence the development of word decoding skills in school children (e.g., Seymour et al. 2003; Ziegler et al. 2010). For one, school children learning to read in transparent orthographies were reported to achieve close-to-ceiling word decoding performances already at the end of first grade, whereas children learning to read in less transparent orthographies were considerably slower (e.g., Seymour et al. 2003). Dyslexic readers were reported to achieve better word and non-word reading performances in transparent orthographies than in less transparent orthographies (Landerl et al. 1997; Paulesu et al. 2001). In their cross-language study with German and English school children Landerl and colleagues compared dyslexic readers (11-12 years old) with a reading level control group using the same task and similar stimuli for the participants in both languages. The German dyslexic readers committed fewer reading errors and were faster in word reading compared to English dyslexic readers. Such cross-language differences in the reading performances were also reflected in the reading level control groups (Landerl et al. 1997). Irrespective of the language, the groups of dyslexic readers performed less well on reading and phonological tasks (e.g., phoneme substitution) when compared to control groups, but the reading impairment was more severe in less transparent orthographies than in transparent orthographies (e.g., Lindgren, De Renzi & Richman 1985). These observations indicate that the overall transparency in the spelling-sound correspondences has an impact on the development of the reading system. Beyond that, skilled word reading in transparent orthographies was shown to be faster than in less transparent orthographies, and the results of accompanying PET (positron emission tomography) studies indicate some differences in the neural activation patterns associated with reading in rather transparent vs. opaque orthographies; e.g. Paulesu et al. (2001). Altogether, these observations lead to the assumption that properties of the orthography are associated with different demands on the cognitive reading system. Moreover, they are well in line with the *Orthographic Depth Hypothesis* (Frost & Katz 1992; Frost, Katz & Bentin 1987) stating that word reading in languages with a transparent orthography might rely to a larger extent on phonological activation than word reading in less transparent orthographies which is assumed to rely more on visual-orthographic information (because the spelling patterns provide more ambiguous phonological cues).

A computer simulation study by Ziegler, Perry & Coltheart (2000) demonstrated that the German orthography can be described by fewer spelling-to-sound translation rules for monosyllabic simple words than English orthography (especially with respect to multi-letter rules). Moreover, Ziegler and colleagues showed that this smaller set of rules suffices to compute the correct pronunciations for a larger amount of words in German as compared to English. The higher degree of spelling-to-sound transparency in small orthographic units (letters, graphemes) in German in contrast to English raises the question whether readers in German rather rely on small size orthographic units during word decoding; i.e., rather on letters and graphemes than on onsets and rimes. This question was for example tackled by Ziegler, Perry, Jacobs and Braun (2001) who observed stronger length effects in German than in English skilled readers when naming single words (e.g., *Zoo* ‘zoo’ vs. *Sturm* ‘storm’). An increase in the total number of letters slowed down the naming performances for a word, and this effect was more pronounced in German than in English readers. This suggests that the presented words were broken down into small spelling units, and that in skilled German reading printed words are subject to more fine-grained sub-lexical segmentation processes (compare e.g., Ziegler, Perry, Ma-Wyatt, Ladner, & Schulte-Körne 2003 for a similar study with young German and English participants on different reading levels). This finding might be attributed to the higher efficiency of the grapheme-to-phoneme conversion rules in German orthography allowing a smaller grain-size for functional processing units during word decoding.[15] Given that printed words are split into smaller spelling units in German the spelling-to-sound consistency of larger units such as orthographic rimes might be less important than the consistency of small size units. To my knowledge, the issue of which different sizes of spelling units are subject to consistency effects in German word reading has not yet been addressed by systematic empirical investigations.

In sum, spelling units which unambiguously map to units of pronunciation were shown to have a processing advantage over spelling units with an inconsistent sound mapping. Moreover, the results of cross-language studies are compatible with the assumption that literate speakers are especially sensitive to those spelling units with a more transparent relation to units of pronunciation (e.g., Ziegler et al. 2001, 2003).

Beyond that, a number of studies indicate that the consistency in the orthography-phonology mapping also plays a role in spoken word processing. For example, a study by Ziegler & Ferrand (1998) showed that sound-to-spelling consistent words were processed faster and more accurately than sound-to-spelling inconsistent words in auditory lexical decision. In their study with French skilled readers words with an orthographically consistent phonological rime, i.e., one that is spelled the same in different words (compare e.g., /ɑʒ/ <age> in *rage, cage* “anger/ rage, cage”) were related to faster and more accurate responses than words with an orthographically inconsistent phonological rime, i.e., one with different spellings in different words (e.g., /õ/ in <omb> in *plomb, nom, ton* “plumb, name, tone”, see e.g., Tranel 1987).[16] The occurrence of sound-to-spelling consistency effects indicates that spelling knowledge is involved in spoken word processing in literate speakers. This view is supported by similar observations of processing advantages for consistent words over inconsistent words from studies on auditory word processing in English and Portuguese (e.g., Ventura, Morais, & Kolinsky, 2007; Ziegler, Petrova, & Ferrand, 2008). Chapter 6 briefly presents a study we conducted to investigate the question

[15] But see Perry, Ziegler, Braun & Zorzi (2010) for an alternative explanation for the cross-language differences between German and English; the authors note that the potentially larger multi-letter units in German (up to four letters in German, e.g., <tsch> vs. up to three letters in English e.g. <tch>) might be responsible for larger effects of word length in German; the parsing of longer letter strings might take longer and demand more focused spatial attention. The number of letters that need to be captured by the attentional window might differ across languages and lead to more or less pronounced length effects (but compare Perry, Ziegler & Zorzi, 2014).

[16] Note that – like the spelling to sound consistency – the sound-to-spelling consistency of single spoken words can be operationalized by a consistency ratio (considering the number of ‘friends’ sharing the same pronunciation and spelling, relative to the number of ‘enemies’ with the same pronunciation but a different spelling).

whether sound-to-spelling consistency affects German spoken word identification and whether this is the case in beginning readers as well as in skilled adult readers.

The reported cross-language data support the view that English, with its rather opaque orthography, might differ from more transparent orthographies with respect to the functional word reading units (e.g., Ziegler et al. 2000; Ziegler et al. 2001; compare also Landerl 2000; Wimmer & Goswami 1994; Goswami, Ziegler, Dalton & Schneider 2001, 2003; Paulesu et al. 2001). The majority of studies in reading research were focused on English (Share 2008); therefore, a lot more future investigations are required to find out whether current word reading models based on empirical findings from, and theoretical accounts for English, can adequately explain word reading in other, more transparent languages like German. In order to contribute to a broader empirical basis for theoretical accounts on word reading the present work is focused on word reading in German which has a more transparent orthography, and which is subject to a considerably smaller number of empirical studies.

2.1.3 Summary

The present chapter summarizes some basic assumptions concerning universal and language-specific properties of the reading system which are more or less uncontroversial in the literature on reading research.

The writing system determines the inventory of perceptual reading units.

Compare for example written Chinese with German; whereas in Chinese the basic units of written language (characters) represent morphemes and syllables; the basic units in German (graphemes) represent phonemes. It is assumed that in alphabetic languages like German the phonological activation during word reading proceeds in a cascaded fashion (Perfetti & Liu 2005; Perfetti 2011). In other words, single sub-lexical orthographic units are identified (e.g., letters, graphemes, syllable components, syllables) which are interconnected to sub-lexical phonological units. The activation of sub-lexical phonological units produces a pre-lexical phonological activation which grows incrementally during the processing of more orthographic constituents of a printed word. In contrast to that, phonological activation might not take place before the lexical access of written words in Chinese because only during or after an orthographic representation – a character that cannot be decomposed into subsyllabic units – is identified, it can make contact to phonological information (for empirical support of this assumption, see Perfetti

& Liu 2005, and references cited therein). Note that in the more "densely packed writing systems" with respect to morpho-semantic content the readers typically process a smaller number of perceptual reading units at a time (compare e.g., the perceptual span for reading Chinese encompasses approximately 4 characters vs. reading English approximately 17-19 letters; Rayner 1998:380).

The activation patterns of the neural network associated with reading varies across writing systems and orthographies.

The reading system and the neural network where the corresponding cognitive operations can be localized accommodates to the writing system (the *System Accommodation Hypothesis*, Perfetti & Liu 2005). This hypothesis is roughly saying that the cognitive system that supports reading adapts to the structure of the linguistic environment in which its processes operate; Frost (2012:266). In other words, the reading system is influenced by language-specific properties such as the writing system and the orthographic system. This view is also supported by findings from PET studies (e.g., Paulesu et al. 2001) suggesting that differences in the orthographic transparency are related to differences in the neural structures that support reading (Perfetti & Liu 2005).

The transparency of the orthographic system influences the reading system.

Different degrees of orthographic transparency in alphabetic languages are not only associated with partially different activation patterns in the brain structures involved in reading, and differences in the prevalence and severity of reading impairments (e.g., Paulesu et al. 2000, 2001). The transparency in the mapping from orthography to phonology is also assumed to affect the grain size of phonological units involved in phonological activation during word reading (e.g., Ziegler & Goswami 2005). In general, spelling units which unambiguously map to sound units are assumed to have a processing advantage over spelling units with an inconsistent sound mapping. Literate speakers seem to be especially sensitive to those spelling units with a more transparent relation to units of pronunciation (e.g., Ziegler et al. 2001, 2003).

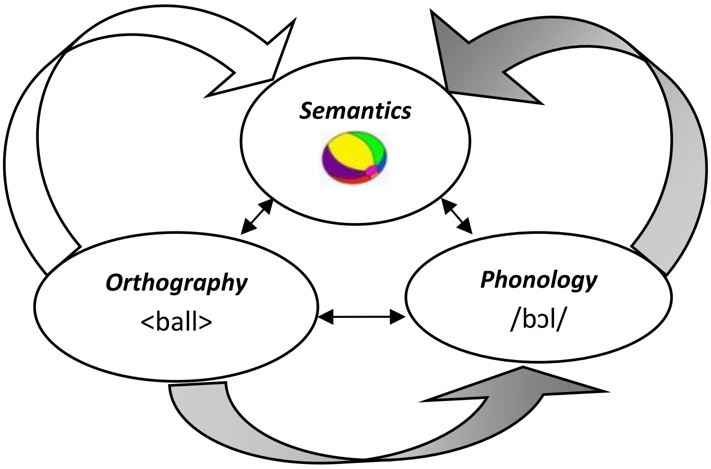
To summarize, the inventory of perceptual reading units (i.e., the language units represented by basic units of the script) is determined by linguistic factors such as the phonological and morphological structure of words and the writing system. In skilled readers the brain structures involved in the reading process are accommodated to the peculiarities of the language, the writing system and the orthographic system. Moreover, the transparency of the orthography-phonology mapping modulates the functional relevance or salience of spelling-sound units of different grain sizes across languages, and, across different words within one language. The next chapter turns to the issue of reading acquisition in order to establish important assumptions on developmental influences on the cognitive reading system.

2.2 The task and the force of reading acquisition

In learning to read the child learns how written language encodes units of the spoken language (e.g., Perfetti & Dunlap 2008; Perfetti 2011). In contrast to spoken language acquisition, reading acquisition is based on intentional learning processes (instruction, exercise and practice). The process of literacy acquisition encompasses explicit learning strategies (such as training sound-spelling translations, correct word spellings, or learning capitalization rules) and implicit learning through print exposure (such as becoming sensitive for licit and illicit spelling patterns; e.g., that an English word never begins with **nk* but may end in *nk*; cf. Klicpera et al. 2010). A proficient reader is not only able to decode and recognize written words, but to understand sentences and texts, and this involves a number of additional, higher-level component processes of the reading system (for example morphological and syntactic integration, sentence comprehension, text comprehension; see e.g., Klicpera et al. 2010; Perfetti 2007 for further details). However, a basic component process of reading is the process of word identification (e.g., Perfetti 2003), and the scope of the present work is restricted to this basic process. Therefore, the term reading acquisition is used here to refer to the acquisition of word reading skills.

In alphabetic languages like English and German, the orthographic representation of a word, the word's spelling, is systematically related to the pronunciation via grapheme-to-phoneme correspondences, though, in English the translation from spelling to sound is less straightforward than in German. However, the spelling-to-sound translation can be captured by correspondence rules (e.g., Ziegler et al. 2000). In contrast, the mapping from a word's spelling to a word's meaning (as well as from pronunciation to meaning) is arbitrary and cannot be accomplished by rule-application (but see Seidenberg & Gonnerman 2000 for a critique). This view is formulated in the *Determinacy Principle* (Perfetti & Liu 2006:230) stating that *"form-form relations are more deterministic than* *form-meaning relations."* Broadly speaking, if meaning cannot be derived from another level of lexical representation (the word's sound or spelling) it must be stored in, and accessed from memory; whereas the spelling can – at least partially – be inferred from phonological information on a word and vice versa. Therefore, it is conceivable that when a reader encounters a written word phonological information is quickly and automatically activated (and vice versa). Moreover, from the determinacy of the orthography-phonology mapping in alphabetic languages it naturally follows that a printed word can be recognized through different pathways–either through a direct mapping from print to meaning or indirectly from the orthographic form to a phonological form to word meaning. In Figure 1, the indirect pathway from print (<bal>) to sound (/bɔl/) to meaning is depicted by two grey arrows, and the direct mapping from print to meaning is depicted by the white arrow on the left-hand side (this figure is a simplified version adapted from Seidenberg 1985).

Figure 1



For one, Figure 1 depicts the relationship between different linguistic levels and the interconnection between each of the lexical components constituting the word (orthographic form, phonological form and meaning); in other words, the figure illustrates the interlocked lexical components that denote a word's identity (Perfetti & Liu 2006). Beyond that, Figure 1 also symbolizes the two pathways that lead from a given orthographic form either direct to meaning or phonologically mediated, i.e. from spelling to sound to the phonological representation to meaning – which is the basis of the so called dual route accounts (e.g., Coltheart et al. 1993; Coltheart et al. 2001). Now, how does the beginning reader learn to decode printed words by either route?

2.2.1 Foundation skills of reading acquisition

Peripheral and central skills

The acquisition of word reading skills is based on more general skills required for learning such as motivation, self-composure, the ability to focus and concentrate on a task, intelligence, meta-cognitive skills such as planning and self-monitoring during the execution of a task, long-term and short-term memory (especially a good auditory and visual working memory), visual-motor and coordination skills (e.g., eye movement control), social and pragmatic skills (because reading, like listening, is an act of communication), as well as world knowledge supporting the correct interpretation of the intended message; for a more extensive overview see e.g., Schründer-Lenzen (2007). Apart from these peripheral skills, some skills are directly related to learning to read, the so-called central skills which are also refined as a consequence of literacy acquisition. Among these, of course, is spoken language development; since written language represents units of the spoken language, the general verbal competence, i.e., the ability to produce and understand utterances is involved in successful reading acquisition, and an impaired spoken language development might interfere with reading acquisition (see e.g., Brandenburger & Klemenz 2009). The general verbal competence comprises phonetic-phonological skills (the ability to articulate, identify, or operate with sound units of the language), knowledge about words (word meanings, pronunciations, sounds, and grammatical properties), as well as morphological, and syntactic skills which were shown to be important factors when it comes to comprehension (e.g., Muter, Hulme, Snowling & Stevenson 2004; Hulme & Snowling 2014).

However, written words are the basic units of written language, and the reading process starts with the identification of words. The successful acquisition of word reading skills is assumed to be the based on understanding the alphabetic principle and using the grapheme-phoneme correspondences to decode written words (e.g., Schöler et al. 2007). In order to understand the alphabetic principle and become a good word decoder the child needs meta-linguistic skills such as the ability to operate with language as an abstract object; or more specifically, the sensitivity for the phonological structure of words and the ability to operate with units of spoken words. Moreover, the identification of written words involves knowledge about words. Thus, the next section sketches metalinguistic skills and knowledge about words as basic foundational skills for the acquisition of word reading skills.

Metalinguistic knowledge

The ability to view language as an object, a certain awareness of linguistic structure (Mattingly 1984, 1992; Downing & Valtin 1984), as well as knowledge about the communicative function and architecture of written language (e.g., Valtin 2010) is a pre-requisite for understanding what reading is about: de-ciphering graphical signs from left to right and top to bottom, with spaces as demarcating single written words which represent spoken words (this is true for European alphabetic languages; other alphabetic languages might be written in other directions, e.g., Arabic, or without spaces between single words, e.g., Thai). Moreover, children learn that written language usually is more formal and explicit than spoken language. The child needs to understand that spoken words have a meaning and a sound, that the word's sound can be isolated and segmented, and that the sound segments can be converted to printed graphical signs. Empirical evidence suggest that experiences with reading books, or, more generally the literacy environment of the child (socio-cultural and familiar background with respect to reading and language practice) promotes a successful reading acquisition (e.g., Hurrelmann 2004).

Beyond this more general meta-linguistic awareness, specifically phonological awareness, i.e., the sensitivity for the structure of spoken language was demonstrated to be an important factor for early phases of reading acquisition (e.g., Liberman & Shankweiler 1985; Perfetti, Beck, Bell & Hughes 1987; Landerl et al. 2013). A task involving phonological processing on the phonemic level is for example "Say mouse without /m/" (phoneme deletion). It was shown that variability in the word decoding and spelling performances can be partially predicted from performances in phonological processing. However, the development in word reading and the development of phonological processing skills are assumed to mutually reinforce each other. For example, Morais, Cary, Alegria & Bertelson (1979) found that illiterate speakers of Portuguese had severe difficulties with phoneme deletion and addition at the beginning of words and non-words (e.g., 'delete the first sound in the non-word PURSO to derive a word' > URSO 'clown'). In contrast, literate speakers of Portuguese performed better on these tasks requiring phonemic awareness. The authors suggest that phonemic awareness is probably achieved and improves during reading acquisition. This plausible explanation is further supported by findings from developmental studies on phonological processing skills, showing that young readers perform better on tasks requiring phonemic sensitivity than do pre-literate children (e.g., Perfetti et al. 1987, Anthony & Lonigan 2004 for English, and Wimmer, Landerl, Linortner & Hummer 1991, Schneider, Küspert, Roth, Vise & Marx 1997 for German, but compare e.g. Cossu, Rossini & Marshall 1993 for a different view) For example, Wimmer et al. (1991) reported that beginning readers from first grade showed better performances in a vowel substitution task (substitution of /a/ with /i/ like in *Gans* > *Gins*), and a phoneme counting task than pre-literate children in their study. Taken together these and similar findings from comparing phonological processing in pre-literate or illiterate vs. literate speakers indicate that the acquisition of orthographic knowledge improves the phonological sensitivity to small-sized phonological units (i.e., phonemes). This is probably due to the fact that in alphabetic languages like German, Portuguese, English or French, the phonemic units that constitute a word are more or less regularly displayed by the same grapheme units in printed words, i.e. they become visible in print. In contrast to the representation of phonemes in written language via graphemes, these small-size units are highly variable in spoken language (e.g., due to co-articulation), and less salient (e.g., due to the short duration of the sound). In printed words, the small sound units that constitute spoken words are by convention always represented through the same spelling units and remain visible to the reader, thus providing supportive information to the memory (Ehri 1992; Perfetti 1992; Taft 2011). Therefore, reading acquisition in alphabetic languages might allow for a more detailed insight into spoken words, and promote the sensitivity for the phonological structure of words. In other words, there is an additional skill that distinguishes readers from illiterates: readers are sensitive for small pronunciation units in words in a way illiterates are not. It seems as if literacy provides an instrument to analyze spoken words in greater detail. Therefore, it is conceivable that the acquisition of orthographic knowledge about words drives a reorganization of the phonological lexicon, from rather shallow to more structured and fine-grained lexical representations (Carroll & Snowling 2001; but see also Ventura, Kolinsky, Fernandes, Querido & Morais 2007).

Knowledge about words

It is obvious that in order to recognize printed words a reader must know words. When learning to read and write, children need to draw upon their knowledge about words (phonological and semantic knowledge as well as morphological and syntactic knowledge). According to estimations young children of six years are familiar with about 3.000 to 5.000 different spoken words constituting their active vocabulary, whereas adults are familiar with approximately 20.000 to 50.000 words actively (Brandenburger & Klemenz 2009; compare e.g., Levelt 1992; Goulden, Nation & Read 1990 for more conservative numbers).

The vast vocabulary growth during the years of primary education (which nonetheless goes on during life-time) is assumed to have an impact on the structure of the mental lexicon. When a child enters primary school, her mental lexicon encompasses several thousand words which might be organized in a network with phonological neighbors and semantically related words connected through their shared features. During written language acquisition a typically developing school child learns many spelling patterns and spelling rules for words. The acquisition of orthographic lexical knowledge is assumed to be based on knowledge about spelling-sound relations, and phonological information on word forms stored in the mental lexicon (e.g., Ehri 1995; Klicpera et al. 2010). In other words, phonological sensitivity and word form knowledge is assumed to be involved in the lexical integration of orthographic knowledge (see e.g., Landerl & Wimmer 2008; Ehri 1995). In addition, the improvement of the quantity and quality of lexical word knowledge is viewed as essential in the development of word reading skills (Verhoeven & Van Leeuwe 2008). The next two chapters give a brief overview of the typical phases in reading acquisition and about assumptions concerning the integration of orthographic information in the mental lexicon of literates.

2.2.2 Phases of reading acquisition

Like the acquisition of spoken language, written language acquisition proceeds in typical phases. Although the course of learning to read differs across individuals, languages, and teaching methods, reading acquisition in alphabetic languages has a common ground. In the literature on the development of reading and writing skills in languages with alphabetic orthographies, the view is widely accepted that the processing of rather coarse visual features of printed words is typical for the initial phase which is called the logographic or pre-alphabetic phase (Frith 1985; Ehri 1998; see also Klicpera et al. 2010). In this phase, children consider written words or symbols alike as a graphical sign for a language unit; they might, for example name company logos they often look at because they recognize their visual features (e.g. *CocaCola*); or, they might already copy letters and letter-like graphical signs, but have not yet discovered that the single components of a visual word systematically represent sound units of the spoken word. In other words, they have not yet gained insight into the basic principle, i.e., the alphabetic principle of the systematic letter-sound relations in written language (e.g., Rozin & Gleitman 1977; Stanovich 1982; Stuart & Coltheart 1988).

The next so-called alphabetic phase initiated by teaching instructions is characterized by the development of both a sequential decoding and a holistic processing route (Klicpera et al. 2010; see e.g., Grainger, Lété, Bertand, Dufau, & Ziegler 2012 for empirical support).

The sequential decoding procedure relies on the systematic relations between units of sound and print which allow for writing down or pronouncing unknown words, whereas the holistic processing route relies on stored knowledge about written words whose spelling patterns have become familiar to the learner by the repeated exposure to these words. In the beginning of the alphabetic phase the children might produce so-called skeletons when writing down words which often contain the more salient consonant letters but lack some (often vowel) letters. The decoding of unknown words first proceeds letter-by-letter and due to exercise and growing experience it becomes faster and more efficient. For example the results of studies by Fayol and colleagues (e.g., Martinet, Valdois & Fayol 2004 on French; compare Share 1995, 1999 on English) indicate that spelling information on specific words is stored in memory already in early phases of reading development. Lexical orthographic knowledge (i.e., knowledge on the spelling patterns of words) can be trained explicitly, and it is also acquired through repeated word decoding with the same material, irrespective of whether this involves reading aloud or reading silently (see e.g., de Jong, Bitter, van Setten & Marinus 2009, and references cited therein). It is assumed that this orthographic knowledge is stored as a new lexical component in the mental lexicon, and thus enriches the lexical information on stored word forms. Note that the additional orthographic information on word forms is to some extend redundant, because spelling-sound relations in alphabetic languages are systematic, hence, the phonological form of a word is partially predictable from its spelling and vice versa (this redundancy follows from the Determinacy Principle, see Perfetti & Liu 2006).

In the third phase (the orthographic phase) both the sequential decoding and the holistic processing routines apply in parallel, and the process of word reading becomes more and more automatized, is thus faster and requires less cognitive capacity (e.g., Verhoeven, Reitsma & Siegel 2011). Due to the increasing automaticity of the word identification process, the reader can focus on higher-level component processes of reading such as information integration and inference making. The set of perceptual reading units which are recognized as a whole becomes larger; e.g., sub-word units like affixes and frequent letter sequences or even whole words are recognized by sight and this allows for a higher speed in word reading (e.g., Klicpera et al. 2010). It is further assumed that success in approaching the orthographic phase heavily relies on massive exposure to and practice with reading texts – thus, reading proficiency is promoted by reading experience.

2.2.3 Integration of orthographic knowledge in the mental lexicon

Due to the smaller vocabulary of pre-literate children and beginning readers the phonological neighborhood of lexically stored words might be less dense than in an adults' mental lexicon, and thus, similar words might be more easily distinguishable already by coarse features (e.g., a different onset or rime, *cat* vs. *rat,* or *rat* vs. *road*). It is assumed that similarity patterns on a certain level of phonological representation help to organize and categorize lexically stored words, e.g., into rime neighbors like *cat, rat* (e.g., Metsala 1997). Here, the invariant shared rime sound becomes available as processing unit. The acquisition of hundreds and thousands of new words as a consequence of maturation and learning processes increases the neighborhood density, and might put pressure towards more refined specifications of lexical units stored in memory. In other words, an increased neighborhood density might necessitate more fine-grained, phoneme-based specifications in the mental lexicon (with respect to orthographic, phonological and semantic information), because more lexically distinctive features are required to allow for the identification of the correct word (and word meaning) in a context. Compare for example the words *cat, cot, kit* and *rat, ran, scratch* which can be best distinguished unambiguously with recourse to syllable components separately. For example Metsala (1997) reported a developmental study investigating the impact of phonological neighborhood density and frequency on spoken word recognition. Metsala conducted a gating experiment with young and adult participants; i.e., the subjects were presented with successively more acoustic-phonetic detail from the onset of a spoken test word, and were asked to guess the target word. All participants needed more acoustic-phonetic detail (higher gating durations) to recognize high-frequency words in dense neighborhoods than in sparse neighborhoods which was assumed to result from a larger number of alternative word candidates in dense neighborhoods. Moreover, with increasing age the subjects needed less acoustic-phonetic input to identify all low-frequent words as well as high-frequency words in sparse neighborhoods. The performance differences across the age groups were smallest with high-frequency words in dense neighborhoods. Metsala interpreted these observations to support the view that an increasing neighborhood density triggers the restructuring of lexical representations from rather holistic forms in very young children to phonologically segmented representations in the older mental lexicon. This restructuring allows for a quick online activation of lexical candidates that match the incoming speech signal already before the complete input is given and makes it easier to discriminate similar lexical candidates. Proponents of the lexical restructuring hypothesis propose that the restructuring of stored phonological word forms is also driven by orthographic information (for a discussion see e.g., Ziegler & Goswami 2005). When spelling information on word forms is acquired and stored in the mental lexicon this increases the visibility of phonemic content, and creates redundancy (from orthography to phonological information). For one, this redundancy follows from the Determinacy Principle according to which phonemic information can be more or less directly deduced from spelling information in alphabetic languages. Orthographic representations reflect phonological properties. For example, in contrast to English, young readers of Korean showed clear-cut preferences for a body-coda division of spoken and written syllables in a similarity judgement task (Yoon et al. 2002). This difference might be attributed to orthographic differences (in Korean, the single graphemes constituting a syllable are located in a square with the onset and nucleus letters posited from left to right in the first row, and coda letters in the second row), as well as to differences in the phonological structure of words (in contrast to English, only few Korean syllables have complex onsets; most syllables in Korean have the structure CV(C)). However, the prevalence of CV(C) syllables is reflected in orthographic representations, thus creating redundant information stored in the lexicon. According to the *Lexical Quality Hypothesis* (Perfetti & Hart, 2001) a large number of lexical representations stored in the memory of skilled readers include highly specific and partially redundant information about words (phonological, orthographic, semantic information). In the process of word identification this bundle of information is retrieved; and, the more specific and reliable (i.e., stable and unambiguous) the faster and more accurate is the processing of this information. These components of lexical information are assumed to be highly interlocked in skilled readers, whereas they are less specific and less connected in younger and less skilled readers. Empirical evidence in support of this assumption comes for example from a study by Landerl et al. (1996). Landerl and colleagues compared young dyslexic and unimpaired readers of English in a phoneme counting and phoneme deletion task employing words with an equal number of phonemes and graphemes versus words with more graphemes than phonemes due to silent letters (e.g., *ham* vs. *lamb*). Landerl and colleagues found that unimpaired readers were heavily distracted by silent letters (e.g., when instructed to delete the first sound in *sword* they erroneously produced (/wo:d/ instead of /o:d/) whereas dyslexic readers were less distracted by spelling knowledge. From the observation that orthographic knowledge was less intrusive in the performances of dyslexic readers, the authors concluded that phonological and orthographic knowledge is less connected, and thus do not strongly co-activate each other (compare also Bruck 1992). From this finding it is conceivable that the orthographic impact on auditory language processing increases as a function of reading skill, i.e., the more extensive and specific the lexical orthographic knowledge of a literate speaker, the stronger both orthographic and phonological forms co-activate each other (see e.g., Ventura, Morais, Pattamadilok & Kolinsky 2004). However, like in reading research, empirical evidence for orthographic influences on spoken word processing from more transparent languages is still notably scarce (e.g., French: Ziegler & Ferrand 1998; Ziegler & Muneaux 2007; or Portuguese: Ventura et al. 2007). In the present dissertation, the question whether orthographic influence on spoken word processing varies as a function of reading experience is tackled by an experiment on German, reported in Chapter 6.

Good phonological processing skills are assumed to enhance the acquisition of orthographic knowledge, and highly specific word knowledge (including pronunciation, spelling and semantic knowledge) is assumed to facilitate the lexical acquisition of new words (see Perfetti 2007, 2011). This view is confirmed by empirical observations of Morais & Mousty (1992) who found that illiterate participants performed much poorer in a non-word repetition task than literate participants, indicating that (automatically) invented spellings for the non-words had helped the literate subjects in correctly retaining and re-producing the nonsense words.

2.2.4 Learning to read in German

By cracking the alphabetic code children are provided with an effective means to decode an infinite number of familiar words, and spell out unknown words. When the initial reading instructions are based on learning and training letter-sound or grapheme-phoneme correspondences (the so-called phonics approach) – which is the standard case in German primary schools – this alphabetic code is taught explicitly, and often accompanied with exercises that help to localize and identify single sounds at certain positions in the word (Klicpera et al. 2010; see also Schründer-Lenzen 2007). However, there are regional differences between instruction methods across federal states, individual schools, and teachers.

According to longitudinal studies with school children from Germany (e.g., Klicpera, Gasteiger-Klicpera, & Schabmann 1993; Schabmann, Schmidt, Klicpera, Gasteiger-Klicpera, & Klingebiel 2009) the pre-literate children coming from kindergarten do not usually bring along the same phonological processing skills preparing them for reading acquisition. This is because the pre-school years are not integrated in a standard education program and so there is a great variety across different kindergartens with respect to training programs preparing the children for learning to read; this is in contrast to for example Netherlands or France, where the play school is an integral part of primary school (e.g., Klicpera et al. 2010:229f). However, in contrast to children learning to read in English, the German beginning readers usually progress quickly during the first year of primary school such that they can correctly read and spell 70-80% of unknown words or pseudowords (Schabmann et al. 2009; see also Klicpera et al. 2010:38; Frith et al. 1998). This is probably due to the relative high degree of orthographic transparency which makes learning the sound-spelling relations in German much less difficult than in English, irrespective of the teaching method employed in school (e.g., Wimmer & Hummer 1990; Klicpera et al. 2010). Usually, children learning to read in German quickly achieve good performances in non-word reading tasks showing good decoding skills already after the first weeks of primary schooling.[17]

The key aspect of the first instructions for beginning readers is the translation of single-letter graphemes to sounds which are blended to form the sound of a printed word (cf. Röber 2008). The grouping of single graphemes in orthographic syllables is usually not taught explicitly in German primary schools (Röber 2008:2). Consequently, the formation of orthographic syllables to allow for the assignment of stress patterns is usually learnt implicitly. The training of sound-spelling correspondences and correct word spellings make the units of pronunciation visible and this visualization is highly transparent in German. It is assumed that this visualization supports the insight into the alphabetic principle and reinforces the sensitivity to the phonological structure of words, which again proves helpful in the construction of the orthographic lexicon (Klicpera et al. 2010). Another important beneficial effect of the visualization of spoken words through their printed forms is the visibility of a shared morphological origin with other words (e.g., *Fernseher* ‘TV’ often reduced to a disyllabic word [fɛɐ̯nzɛɐ], and *sehen* ‘to see, to view, to watch’, often pronounced as one syllable [ze:n], Röber 2010). Spoken language is usually less explicit with respect to the pronunciation of weak syllables and reduced vowels, and thus, a semantic relation might become visible only in the printed word forms. It is assumed that the more specific the phonological, orthographic and semantic knowledge about words, the more stable and unambiguous its lexical representation and this is assumed to enhance the processing speed and accuracy (e.g., Perfetti 2007).

Unlike English, in German words the (minimal) number of syllables a written word contains can usually be determined by the number of uninterrupted vowel letter sequences

[17] Hence, Wimmer & Hummer (1990) claim that there is no compelling empirical support for the logo-graphic phase in German reading acquisition.

(see Neef, 2004). There are only a few exceptions from written words that represent more phonological syllables than uninterrupted vowel letter sequences (e.g., *Klient* corresponding to a disyllabic /kli:.ɛnt/, or *Museum* to a trisyllabic word /mu.ze:.ʊm/). None of the Standard German written words contains fewer syllables than vowel letter sequences. In contrast, English words for example often contain a silent final <e>; compare e.g., *steak* vs. *stake*, or they might contain phonological syllables that are not represented by a vowel letter; e.g., *rhythm*, for a more detailed discussion, see Neef (2004). Moreover, in German, the vowel quality is unambiguously expressed by the vowel letter; only the vowel tenseness might be undetermined, or be signaled by the orthographic syllable structure like in Dutch (compare Chapter 2.1). Altogether, the orthographic form of words reflects the phonological syllable and syllable components rather straightforwardly.

Given the assumption of an automatic phonological activation involving supra-segmental features, does word stress play a role in polysyllabic word reading, and is there a developmental change in the role of lexical stress? In intonation languages like German the position of primary stress is variable, and cannot simply be predicted by the relative position of a syllable in the word. German orthography is viewed as underdetermined with respect to word stress (Neef 2005:22), which is not explicitly marked. Stress patterns can only be assigned implicitly. But is word stress at all involved in silent single word reading in German?

3. Aims and outline of the thesis

First, when a child learns to read words her task is to find out how written language encodes units of the spoken language. There are significant cross-language differences in the way this is accomplished by the employed writing system and orthography, and the cognitive reading system individual to a language is accommodated to such language-specific properties. A comparison of reading acquisition across languages indicates that beginning readers are developing language-specific reading systems that might rely on different functional reading units. However, for any alphabetic language an automatic phonological activation is assumed to contribute phonological information during the word identification process.

In the light of the underrepresentation of languages other than English the present dissertation focuses on word reading in German. The investigation of German word reading is particularly interesting because it has a more transparent mapping from orthography to phonology, but a common origin with, and a similar phonological structure to English.

When considering polysyllabic word reading, the issues of syllable segmentation and stress assignment necessarily come into play. According to the *Implicit Prosody Hypothesis* (Fodor 1998, 2002) skilled readers automatically assign a prosodic contour to written sentences (sentence and phrase level prosody). Metrical information from the word-level is a basis for the higher-level prosodic organization that affects the syntactic and semantic interpretation of spoken utterances. However, whether or not word-level prosody is involved in silent word reading (compare e.g. Ashby 2006; Frost 1998) has not yet been extensively investigated across languages, and it is related to the more general question of which levels of phonological representation are involved in the phonological activation in silent word reading (e.g., Morais 2003). More specifically, this work aims to shed light on the role of word stress as potential reading units in German. Chapter 4 and 5 are concerned with the following questions.

1. Does lexical stress constitute a processing unit in German word reading? And does the functional relevance of word stress vary as a function of reading experience?

2. Do spelling patterns of German words provide potential cues to word stress?

In order to address the first question, Chapter 4 briefly reports an experimental study on silent single-word reading in German, exploring whether there are differences between experienced adult readers and young, less experienced readers in the processing of lexical stress (Beyermann & Penke 2014b). Subsequently, Chapter 5 reviews a corpus study on orthographic stress cues in German disyllabic words (Beyermann 2013) which investigates whether word endings provide potential cues to which syllable in a word is stressed. More generally, both Chapters 4 and 5 intend to contribute to a broader knowledge about polysyllabic word reading in alphabetic languages.

However, the question which phonological units are activated during word reading is related to the issue of co-activation of phonology and orthography in literates. Given that phonology is automatically activated during written word processing, does orthography also come into play during auditory word processing? Chapter 6 reviews Study 3 (Beyermann & Penke 2014a) which is concerned with the following questions.

3. Does spelling knowledge influence spoken word processing in German? And does the influence of spelling knowledge on spoken word processing vary as a function of reading experience?

It seems plausible that the impact of orthographic knowledge on auditory word processing varies as a function of reading proficiency, i.e., that the co-activation of orthographic knowledge is stronger in skilled and more experienced readers than in less skilled, younger readers. The questions whether, and from which stage of reading development, spelling knowledge is involved in auditory word processing in German, and whether the impact of orthographic knowledge increases with reading age, are addressed by an auditory lexical decision experiment with different groups of German readers (school children, and adults) reported in Chapter 6. If spelling knowledge impacts spoken word processing, this would emphasize that acquired orthographic knowledge plays a role beyond the mere production of correct spellings during reading development and provide additional evidence against a specific tuition method currently employed in some primary schools in Germany. Finally, Chapter 7 discusses the study results with respect to their theoretical implications on word processing.

4. Study 1: Word stress in German single-word reading*

This chapter reports a study of Beyermann & Penke (2014b) which aimed to gain insights into the role of word stress in German silent word reading. Given the assumption of an automatic phonological activation involving supra-segmental features, does word stress play a role in word reading, and is there a developmental change in the role of lexical stress? In languages like German the position of primary stress is variable, and cannot simply be predicted by the relative position of a syllable in the word. German orthography is viewed as underdetermined with respect to word stress (Neef 2005:22), which is not explicitly marked. According to the *Default Metrics Hypothesis* on word stress in spoken word production by Levelt, Roelofs & Meyer (1999), patterns of subdominant stress are lexically stored, whereas dominant stress is assigned as a default pattern. Following this line of argument, reading words with dominant vs. subdominant stress might be related to some differences in processing. However, empirical studies on lexical stress in German were primarily focused on different factors influencing stress assignment (e.g., Janßen 2004; Röttger, Domahs, Grande & Domahs 2012), and the question whether the potential role of word stress in word reading is modulated by reading development has not yet been addressed.

4.1 Research question and method

Study 1 investigates whether word stress plays a role in German visual word identification, and whether the role of word stress differs across readers from different stages of reading development. If word–level prosody is involved in silent word reading this would support the Implicit Prosody Hypothesis (Fodor 1998; 2002). A visual lexical decision experiment was conducted, comparing the performances for disyllabic German nouns with a dominant vs. subdominant stress pattern (e.g., *Datum* ‘date’ vs. *Natur* ‘nature’), and the performances of three different age groups were compared. The idea is that if response times or accuracy rates are different for words with a dominant vs. subdominant stress pattern this implies that word stress influences silent visual word processing.

Participants

Two groups of primary school children (27 third graders, mean age 8;8 years, and 27 fifth graders, mean age 10;10 years), and 27 adults (mean age 27;7 years) participated voluntarily.

*Beyermann, S. & M. Penke (2014b). Word stress in German single-word reading. *Reading Psychology*, 35(6), 577-600.

Stimuli and Design

The set of disyllabic target words consisted of 12 words with the dominant stress pattern (e.g., *Datum* ‘date’) and 12 words with a subdominant stress pattern (e.g., *Natur* ‘nature’). Words in both conditions were matched one-to-one for lexeme frequency, word length, and visual similarity. None of the stimulus words contains a schwa syllable which cannot bear stress in German words. Moreover, the orthographic syllable structure was held constant across conditions.

Procedure

One to 4 subjects were tested on separate computers in a quiet room. Each participant first completed 10 practice trials, and was then presented with 50% non-words and 50% words. Three item pairs in the reaction time data of the school children were removed due to high error rates (>50%). This did not affect the matching item factors across conditions. The data were subjected to a 2 x 3 analysis of variance (ANOVA) evaluating the factors *Dominance* (dominant vs. subdominant stress pattern) as within-subject factor and *Age* (i.e., participant group) as between-subject factor.

4.2 Results

Table 1. Subjects’ Performances on Stimulus Words with Subdominant and Dominant Stress

	Error Rates (%) *M (SD)*		Response Times (ms) *M (SD)*	
Group	Dominant	Subdominant	Dominant	Subdominant
3rd grade	**9.1**	**18.1****	**1565**	**1693***
	(10.2)	(8.8)	(358)	(356)
5th grade	**8.2**	**17.3***	**1149**	**1238***
	(10.5)	(12.1)	(294)	(362)
Adults	2.2	3.1	748	746
	(4.9)	(5.7)	(181)	(143)

Note significant effects of *Position* are indicated by boldface numbers
* signals p-values $p < .05$, and ** stands for p-values $p < .001$

For an overview of the data see Table 1. As indicated by the boldface numbers, the ANOVA found that in the younger participant groups from 3rd and 5th grade of primary school, the responses to subdominant stress words were significantly slower and less accurate than those for dominant stress words. In contrast, no effect was detected in the performance data of the adult readers.

4.3 Discussion

The results show that the performances of the school children were significantly affected by the words' type of stress pattern. In contrast, no stress effect was observed in the performances of the adult participants. In other words, at least in earlier stages of reading development, word stress seems to be processed in silent word reading.

It might be assumed that in young readers the assignment of subdominant word stress is related to higher cognitive processing costs than the assignment of the dominant stress pattern. This could be interpreted in terms of the Default Metrics Hypothesis (Levelt et al. 1999). A general probabilistic cue towards the major pattern – the default pattern – is simply derived on the basis of the stress distribution in the phonological lexicon (compare Colombo 1991). Young readers might automatically assign a default stress pattern to printed words which leads to a correct match for words with the dominant stress pattern (e.g., *Datum* 'date') but to a mismatch in words with a subdominant pattern (e.g., *Natur* 'nature') as soon as the lexically stored subdominant stress pattern becomes available[18]. In other words, the mismatch is assumed to arise from conflicting information on word stress coming from different sources (default assignment and lexical look-up), which leads to increased response time latencies and higher error rates in the young readers.

Why did the performances of the adult readers display no stress dominance effect? It seems plausible that skilled readers exploit implicit orthographic or other cues to word stress, i.e., that experienced readers are more sensitive to potential orthographic cues to word stress. The presence of such potential cues to word stress has so far not been studied extensively for German. Although the test words were matched for properties such as word length and orthographic syllable structure, there might be consistency relations between spelling and stress patterns which could have been exploited by the adults (e.g., in word endings, or other structural features of the visual word). In order to shed light on this issue the following chapter reports a corpus study of Beyermann (2013).

[18] In line with dual route theories (e.g., the DRC, or the CDP++ model of reading) the lexical information also containing metrical features, might either be retrieved via the lexical route or after a silent 'sub-vocalization' process, i.e., when a phonological representation of the word is generated via the sub-lexical route.

5. Study 2: Orthographic cues to word stress*

The article of Beyermann (2013) is concerned with the investigation of spelling patterns as potential orthographic cues to word stress in German word reading. The absence of a stress effect in German skilled readers reported in the previous section might be attributed to the processing of such orthographic cues to word stress.

Experimental studies on English, Italian and Spanish visual word processing suggest that certain spelling patterns provide information on word stress, and that such cues are processed by skilled readers (e.g., Kelly et al. 1998; Colombo 1991 on Italian). Recently, a word production study of Röttger et al. (2012) demonstrated that when German skilled readers produce pseudowords the location of the main stress position is influenced by the orthographic complexity of the final syllable rime. In other words, when the final syllable of disyllabic words contained more complex orthographic rimes they were more likely to be stressed. From this observation the authors conclude that the orthographic weight of the final rime was one among other structural factors that determine which syllable received the main stress. More generally, the reading experience might allow skilled readers to gain implicit knowledge on such potential cues to word stress provided by word spellings.

5.1 Research question and method

Do spelling patterns of written words in German provide information on the word's stress patterns? Can word stress be predicted by systematic correspondences between stress patterns and spelling patterns?
All disyllabic German noun lemmas were extracted from the CELEX lexical database (Baayen, Piepenbrock & van Rijn 1993). The number of word final consonant letters and a random set of word endings were investigated as potential orthographic cue to word stress. The idea was that if a spelling pattern predominantly occurs with a specific stress pattern, this spelling pattern constitutes a potential orthographic cue to that stress pattern.

5.1.1 Collection of corpus

The total corpus set consisted of 7933 disyllabic simplex and polymorphemic nouns. In addition, 85 randomly selected word endings from the total corpus were listed.

* Beyermann, S. (2013). Orthographic cues to word stress in German: Word endings and number of final consonant letters. *Written Language and Literacy,* 16(1), 32-59.

In the literature, there is an ongoing debate on whether polymorphemic words are automatically split into their constituent morphemes in an early, pre-lexical stage of word identification (see e.g., Taft & Forster 1975, Butterworth 1983, Zwitserlood, Bölte & Dohmes 2002). If so, it might be that orthographic cues to word stress are relevant only for separate word units (single morphemes). To take into account that orthographic stress cues might be only relevant for single morphemes, separate analyses were conducted, first on the total corpus of disyllabic nouns, including polymorphemic as well as simplex nouns, and second inspecting a sub-corpus containing only the 3318 simplex nouns from the total corpus.

Number of final consonant letters as potential orthographic cue

Each word from the noun corpora was allocated to one of four categories: V (ending in a vowel letter), VC (ending in one consonant letter), VCC (two final consonant letters), and VCCC (three/four final consonant letters). Afterwards, the stress distribution of each of the categories (V, VC, VCC, and VCCC) was determined by counting words with initial and final stress.

Word endings as potential orthographic cue

In a second step, two different sets of randomly selected word endings were investigated: first the total set of randomly selected 85 different word endings, and second, a subset of 24 word endings which included only those endings contained in simplex nouns.[19] For each word ending, the individual stress distribution was determined by counting all words containing this ending, and the number of words with initial vs. final stress.

5.1.2 Comparisons of observed and expected theoretical stress distributions

When the given word ending or category was predominantly associated to words with the same stress pattern, it was assumed to be related to that pattern. Goodness-of-fit tests were employed to compare the observed stress distribution for a given spelling pattern to a theoretical random distribution of stress patterns, and Cohen's $\hat{w}$ (see e.g. Cohen 1988) was calculated to estimate the relative strength of any detected association between a spelling and a stress pattern.

[19] The 85 word endings were contained in 5764 out of 7933 different nouns from the corpus, and the 24 endings were contained in 2413 out of 3318 different simplex nouns.

5.2 Results

The number final consonant letters as stress cue in the total noun corpus

For the total noun corpus of 7933 words, significant departures from a theoretical random stress distribution were detected in all categories (V, VC, VCC, and VCCC), i.e., initial stress is reliably associated with all categories. Thus, not surprisingly, our results confirm that German disyllabic nouns are predominantly stressed on the first syllable, no matter how many final consonant letters are present in the word ending. Consequently, the number of final consonant letters does not indicate a certain stress pattern.

The number of final consonant letters as cue to stress in simplex nouns

In the sub-corpus of simplex nouns the statistical analyses of the frequency counts for initial vs. final stress in words ending in V, VC, VCC and VCCC show that words ending in V and VC are associated with stress on the first syllable. This means that the presence of none or a single final consonant letter in disyllabic nouns indicates initial stress. In contrast, words ending in two final consonant letters are related to final stress. No predominant stress pattern was identified for words with three or more final consonant letters.

Knowledge about the distribution of stress patterns in words ending in V, VC, VCC might allow a strategic stress assignment in simplex nouns (‘Assign initial stress to words ending in V or VC, and final stress to words ending in VCC’). Such a strategy would lead to 79 % correct stress assignments. As a comparison, a default stress assignment of initial stress to all disyllabic simplex nouns would lead to 74%, and thus, fewer correct stress assignments.

Word endings as cue to stress in the total noun corpus

Out of the 85 randomly listed word endings, six are associated with final stress, and 63 are related to initial stress. Sixteen endings have no significant prevalence of either stress pattern. The 69 endings associated with one stress pattern are contained in 5353 different nouns from the total corpus (68% of 7933). If initial stress was assigned as a default pattern in these words, this would result in incorrect stress patterns in 5.5% of the cases, namely for all 297 words with final stress containing the inspected endings. In contrast, a strategic stress assignment by exploiting word endings as stress cues would reduce the amount of incorrect assignments to 3.3% (176 out of 5353). Incorrect patterns would result from exceptional relations between stress patterns and word endings. Thus, a stress assignment strategy based on word endings as stress cues would be more successful than a default assignment procedure.

Word endings as orthographic cue to stress in simplex nouns

Out of 24 word endings from the simplex corpus, 23 were associated with one stress pattern, thereof 13 with initial stress, and 10 with final stress. The 23 word endings are contained in 2396 different words from the corpus of 3318 simplex nouns. A strategic stress assignment based on knowledge about these 23 endings would result in only 3.7% incorrect stress patterns. Compare this to a default strategy assigning the most frequent stress pattern – initial stress – to all disyllabic nouns, which would lead to 10.6% incorrect stress patterns.

5.3 Discussion

The results revealed that the number of final consonant letters is indicative of the stressed syllable in German disyllabic simplex nouns. Moreover, word endings can be an effective cue to word stress in disyllabic nouns, irrespective of whether they are polymorphemic or simplex. Words sharing the same word ending and the same stress pattern are 'stress-friends'. It seems conceivable that words with many stress-friends have a processing advantage over words with many stress-enemies. This is an interesting question for future research. In sum, the results show that certain spelling patterns in words indicate the word's stress pattern. Thus, the present corpus investigation supports the view that there are orthographic cues to word stress in German which might be processed by skilled readers.

6. Study 3: Orthographic consistency in spoken word identification*

The findings reported in the previous chapter support the assumption that silent reading involves a phonological representation of word forms. This chapter now turns to the question whether there is a mutual interaction between orthographic and phonological information processing, i.e., whether orthographic information plays a role during auditory word processing like phonological information plays a role in visual word processing. We addressed this issue in the study Beyermann & Penke (2014a) which is briefly reviewed below.

In the course of literacy acquisition, readers learn about word spellings, for example that the word *sting* /stɪŋ/ is spelled <sting>. Note that some sound units are sound-to-spelling consistent because they are always spelled the same in different words containing it (e.g., the rime sound /ɪŋ/ always spelled <ing> in *king, ring, sling, thing* etc.). Compare this to the rime sound in *bird* which is sound-to-spelling inconsistent because it is spelled differently in other words (e.g., *heard, curd*). The results of a number of empirical studies imply that literate speakers are affected by the sound-to-spelling consistency during spoken word processing (e.g., Glushko 1979; Ziegler & Ferrand 1998). Words with consistent phonological rimes (e.g., *sting*) were documented to have a processing advantage over words containing sound units related to different spellings in different words (e.g., *bird*). This indicates that spelling patterns which are stored in the mental lexicon are involved in the auditory processing of words. It is conceivable that good readers and spellers who have fast access to a rich orthographic lexicon, are more affected by consistency than poor readers and spellers with a slower access to less specific or stable orthographic representations in their mental lexicon. In other words, orthographic effects on auditory language processing might be directly linked to the quality of the stored orthographic knowledge (e.g., Share 2004). However, the results reported by Goswami, Ziegler & Richardson (2005) indicate that consistency plays a role during auditory word processing already in young German and English readers after one year of schooling.

6.1 Research question and method

Beyermann & Penke (2014a) conducted an auditory lexical-decision study to investigate whether sound-to-spelling consistency affects German spoken word processing, and whether there is a difference between speakers from different stages of reading

* Beyermann, S. & M. Penke (2014a). The impact of orthographic consistency on German spoken word identification. *International Journal of Disability, Development and Education*, 61(3), 212-224.

development. We expected better performances on consistent words than on inconsistent words. This observation would imply that spelling knowledge was involved in the task, and thus suggest a close link between orthographic and phonological information on word forms in the mental lexicon.

Participants

Eighteen second graders (mean age 6;7 years), 21 third graders (mean age 8;6 years), and 23 fifth graders (mean age 10;8 years) from regular primary schools, and 21 adults (mean age 26;4 years) were tested.

Stimuli and Design

Thirty-two monosyllabic simplex nouns, with 16 containing sound-to-spelling consistent rimes (e.g., *Ring*, containing /ɪŋ/ always spelled <ing>), and 16 containing inconsistent rimes (e.g., *Stahl*, containing /ɑl/ which can be spelled <al, aal, ahl>, e.g., *Tal, Stahl, Aal* ‘valley, steel, eel’) comprised the test items. Item factors such as uniqueness point, word/syllable frequency, phonological/orthographic rime frequency, number of orthographic neighbors, word length and presentation duration were balanced across conditions. All test words are spelling-to-sound consistent (rime spelling always pronounced the same in different words).

Procedure

Small groups of participants (1-4) in a quiet room were instructed to decide as fast and as accurately as possible whether a presented word was a real German word.

From the data of the 2nd graders three item pairs were removed due to high error rates (>50%). This had no impact on the counter-balanced item factors across the experimental conditions. The data were submitted to a 2 x 4 ANOVA with *Consistency* (consistent vs. inconsistent rimes) as within-subject factor and *Age* as between-subject factor.

6.2 Results

A significant interaction of *Age*Consistency* in the ANOVA on accuracy data indicated that *Consistency* has an impact in some but not all age groups in our experiment. Subsequent within-group comparisons revealed a significant main effect of *Consistency* in the 2nd graders (indicated by boldface numbers in Table 2). A significant main effect of

Consistency, but no interaction of *Age*Consistency* was found indicating that the response times of all groups were affected by the factor *Consistency*. Table 2 gives an overview of the performance data.

Table 2. Performances of the Participants on Words with Consistent vs. Inconsistent Rimes

	Accurracy Rates (%) *M (SD)*		Response Times (ms) *M (SD)*	
Group	Consistent	Inconsistent	**Consistent**	**Inconsistent****
2nd grade	**86.8 (8.7)**	**80.3 (12.4)***	**829 (157)**	**835 (126)**
3rd grade	93.8 (7.1)	91.9 (7.4)	**596 (102)**	**654 (144)**
5th grade	90.8 (7.0)	93.8 (5.9)	**482 (97)**	**527 (103)**
Adults	98.5 (3.4)	97.6 (3.7)	**359 (102)**	**373 (88)**

Note significant effects of *Position* are indicated by boldface numbers
* signals p-values $p < .05$, and ** stands for p-values $p < .001$

6.3 Discussion

The results show that spelling-to-sound consistency has an impact on spoken word processing in German literate speakers from different stages in reading development. Consistent words had a processing advantage over inconsistent words as was displayed in shorter mean response latencies in all subject groups. Moreover, the 2nd graders were more accurate in accepting consistent words than inconsistent words. The performance accuracy of the three older participant groups was not affected by consistency which might be due to the fact that they achieved overall high accuracy scores.

The results indicate that sound units of words which are associated with different alternative spellings are related to higher processing costs than sound units of words which are consistently expressed by the same spelling pattern. In contrast to our expectations, the assumption that orthographic consistency is more relevant for experienced than for less experienced readers is not supported by our data, since there is no qualitative difference across the groups.

A plausible explanation for consistency effects is provided in Taft (2011). The auditory language input that listeners perceive is highly variable (e.g., due to speaker variation, co-articulatory processes), and the physical nature of speech input is transient, i.e., the input is available only for a short moment. Taft suggests that literate speakers automatically build up an abstract phonological representation based on available spelling knowledge to support the auditory working memory with additional and physically stable information on the input. Additional, supportive spelling information on the auditory input might facilitate the activation of candidate words during lexical search. If the speech input is related to only one stored spelling pattern, i.e., the available additional spelling information is consistent, this might lead to a more specific abstract representation as compared to auditory input associated with alternative spelling patterns in different words. Accordingly, unambiguous spelling information is more supportive than inconsistent spelling information, such that the less ambiguous the representation of a spoken word in print is with respect to sound-spelling conversions, the more specific or the more quickly is the built-up of an abstract representation for a spoken word. Following this line of argument it seems plausible that the less reliable and frequent the connections between units of sound and units of spelling for a spoken word, the less supportive is the knowledge on the correct word spelling during auditory processing.

7. General discussion

The presented findings of this work shed light on the close link between units of spoken and units of written language in literate speakers of alphabetic languages, contributing to our knowledge about the word identification process in German throughout different levels of reading proficiency. In the past the majority of studies in reading research were concerned with monosyllabic word reading in English (Share, 2008). But reading encompasses the identification of many polysyllabic words as well. When considering polysyllabic word reading, the issues of syllable segmentation and stress assignment come into play, raising the question whether an automatic phonological activation– i.e., when a pronunciation of polysyllabic words is generated–involves higher-level, prosodic units such as syllables and word stress. On the background of the underrepresentation of languages other than English the present dissertation focused on word reading in German. More specifically, this work aimed to shed light on the role of word stress as potential reading unit in German investigating the questions:

1. Do supra-segmental phonological units such as lexical stress constitute processing units in German word reading? And does the functional relevance of these units vary as a function of reading experience?
2. Do spelling patterns of German words provide potential cues to word stress?

Polysyllabic words which are often fixated more than once (e.g., Rayner 1998) are assumed to be processed syllable by syllable (e.g., Conrad & Jacobs 2004; Stenneken, Conrad & Jacobs 2007). The results of Study 1 show that word-level prosody is involved in silent word reading at least in young German readers (Chapter 4), and thus support the view that phonology shapes the functional reading units in visual word processing.

7.1 Word stress as reading unit

The empirical observations reported in Chapter 4 indicate that young readers of German automatically impose a stress pattern during word reading. In Study 1 (Beyermann & Penke 2014b), the typicality or dominance of a word's stress pattern (initial vs. final stress) was shown to influence the performances of the school children, whereas the performances of skilled adult readers were not affected by stress dominance. It is conceivable that readers draw upon implicit knowledge about the frequency distribution of stress patterns in the language, especially in earlier stages of literacy development. Less experienced readers are assumed to lack implicit knowledge of stress cues, and thus they might show strong effects of stress dominance. We hypothesized that the young readers have assigned the most frequent stress pattern as a default pattern, whereas the skilled readers participating in the experiment were sensitive to implicit stress cues from frequent associations of spelling patterns and stress patterns. More experienced readers might be sensitive to stress cues provided by orthography (e.g., word endings, number of final consonant letters) allowing to predict the position of a stressed syllable in printed words, such that due to stress prediction, words with a subdominant stress pattern were not related to processing difficulties in skilled reading.

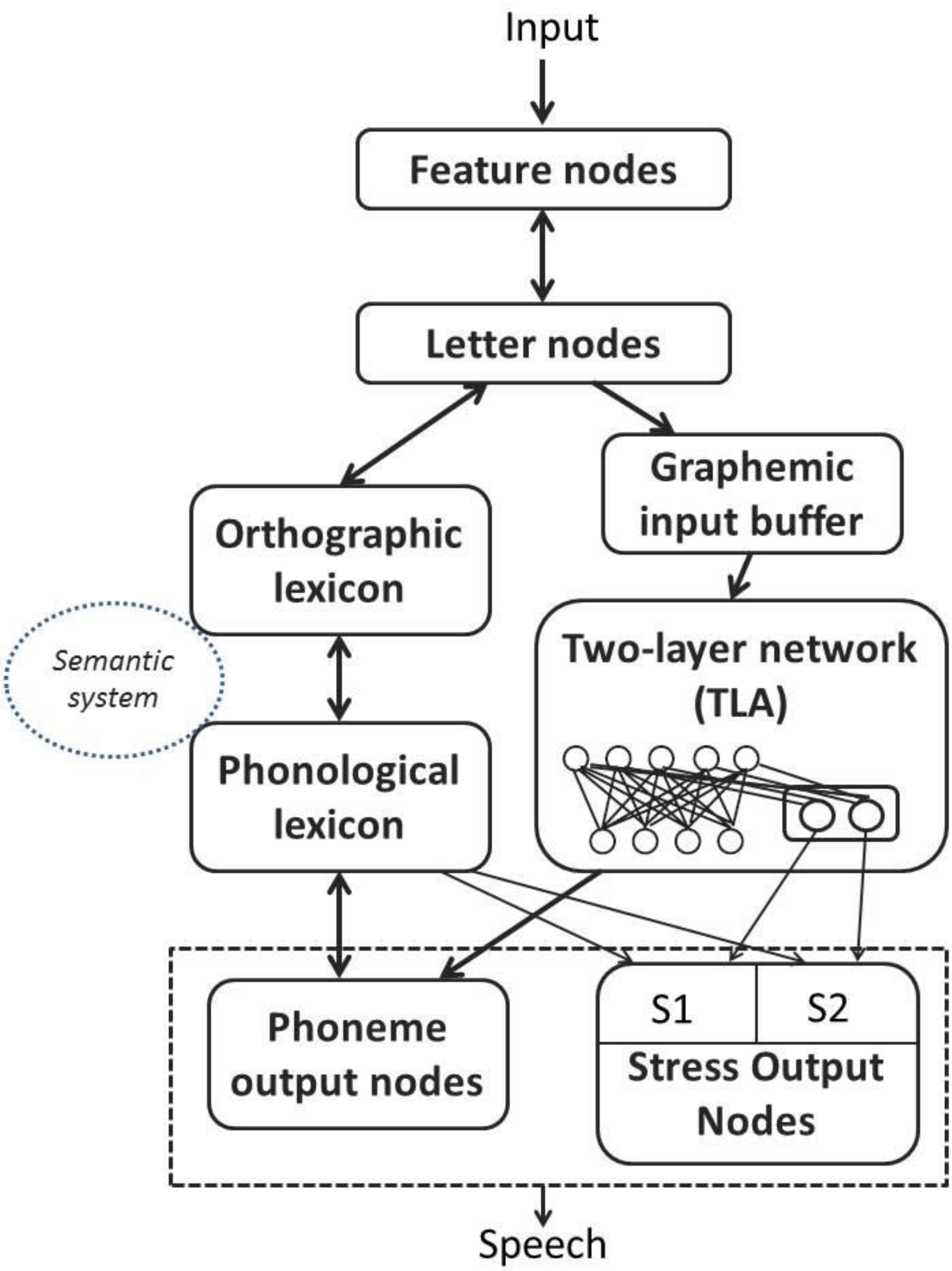
The observation that adult readers showed no stress effect in Study 1 might be interpreted to show that word stress is not involved in skilled silent reading. However, for one, this explanation is in conflict with phonological effects on the performances of German adult readers which were reported in a number of studies, and indicate that skilled readers automatically generate a phonological representation of written words (e.g., Ziegler & Jacobs 1995; Ziegler, Jacobs & Klüppel 2001; Ziegler et al. 2001; Penke & Schrader 2008). Moreover, the results of Study 2 (Beyermann 2013, Chapter 5) revealed that there are indeed reliable orthographic cues to word stress in disyllabic German nouns which might be explored by skilled readers. A number of word final spelling patterns that frequently correspond to the same stress pattern were identified as potential orthographic stress cues. In other words, spelling knowledge can be seen as a source of information to assign stress, and distributional knowledge on these orthographic cues might be involved in visual word processing. It remains an interesting question for future research whether such word endings or other potential orthographic cues to word stress are processed by skilled German readers. Preliminary results of a visual lexical decision study with university students indicate that word endings are indeed processed as orthographic cues to stress in silent word reading (Beyermann, unpublished manuscript). In this experiment, the dominance of the stress pattern (i.e., the typicality or frequency of occurrence) influenced the task performances of the adult participants, i.e., they showed faster responses to disyllabic words with initial stress (e.g., *Kokos* ‘coco’, *Platin* ‘platinum’) than to words with final stress (*Visier* ‘sight, backsight’, *Tresor* ‘safe’). Moreover, words with a stress consistent ending (e.g. *Kokos, Visier*) – i.e., having more “friendly” neighbors that share the same word ending and the same stress pattern than “unfriendly” neighbors sharing the same word ending but a different stress pattern – had a processing advantage over words with an inconsistent stress ending (like *Platin*, *Tresor*). This indicates that stress cues available from print were automatically processed by skilled readers. In other words, stress dominance and stress consistency independently contributed to variations in the task performances. Thus, like the young readers in Study 1, the skilled readers showed a dominance effect when the stress consistency of the ending was controlled for. These preliminary results indicate that word stress is involved in young as well as in skilled adult word reading.

In sum, the reported findings support the view that lexical stress, i.e., a prosodic surface property of phonological word forms is automatically processed during silent word identification in young, less experienced German readers. Future research on multisyllabic word reading should consider the typicality of word stress (i.e., the lexical dominance of a pattern) as well as the consistency of available stress cues as an inhibitory/facilitative factor for the participants' task performances. Moreover, the assignment of lexical stress should be implemented in current reading models.

Stress effects in the Connectionist Dual Process model (CDP++)

The observed stress dominance effect could be accommodated in the theoretical framework of the Connectionist Dual Process model for polysyllabic word reading (CDP++, Perry, Ziegler & Zorzi 2010). Until today, only few models include mechanisms for lexical stress assignment (e.g., the PDP, discussed in Pagliuca & Monaghan 2009). The CDP++ includes a stress assignment mechanism based on an associative network connecting stress output units and spelling units (see Figure 2).

Figure 2: The architecture of the latest version of the CDP++ in running mode (adapted from Perry et al. 2010). The figure depicts a simplified version.



The CDP++ includes a stress assignment mechanism composed of two pathways for assigning stress: a lexical look-up of stored metrical information from the phonological lexicon and a sublexical procedure that computes a stress pattern based on statistical spelling-sound relations. Metrical information from the sublexical and the lexical pathway activate the stress output nodes in the phonological output buffer (represented by the dotted rectangle at the bottom of the figure).

In beginning readers, the output buffer is biased towards the most frequent, i.e., the dominant stress pattern in the phonological lexicon (i.e., in the spoken vocabulary). This predisposition towards a default stress might be implemented by a slight pre-activation of S1 as opposed to S2 (S1=initial stress, S2=final stress). This gives words with the dominant stress pattern a general advantage over words with a subdominant pattern, because less additional metrical information is needed until sufficient coherent information is pooled in the output buffer, and the visual input can be identified and accepted as a word. In contrast, the pre-activation of S1 makes word identification more effortful and slower for words with a subdominant stress pattern, because the pre-activation of S1, a misleading bias, is incongruent with the metrical information contributed from the phonological lexicon after lexical access. This contradictory bias has to be overcome by additional metrical information from the lexical or sublexical route which requires additional processing. Take as an example a written word with a subdominant stress pattern, like *Natur* ‘nature’. The pre-activation of S1 would lead the reader to rather assign first syllable stress when no implicit stress cues are available. And due to a lack of implicit knowledge on stress cues, less experienced readers are more likely to assign the most frequent stress pattern as a default. Hence, they show strong stress dominance effects. The observed dominance effect in young readers (Chapter 5) complies with this assumption. Interestingly, the model predicts that stress dominance should independently affect the readers’ performances across all age groups as long as the pre-activation of S1 is perpetuated.

It is assumed that with growing reading proficiency the readers learn subtle statistical relations between spelling patterns and stress patterns, hence gaining access to different potential cues to word stress (e.g., word endings, letter clusters, onset or coda complexity in written words; see e.g., Arciuli, Monaghan & Seva 2010). The two-layer associative (TLA) network of the CDP++ reflects this distributional learning in that spelling patterns (single or multi-letter graphemes, letter sequences) are not only associated with phonemes but can also be associated with metrical information (e.g., Perry et al. 2010). In Figure 2, these interconnections in the TLA network are represented by the bubbles, with the topmost layer representing onset, nucleus and coda graphemes nodes, the lower level standing for the associated phonemes, and the slightly bigger bubbles on the right-hand side depicting the sublexical stress input nodes which are likewise connected to the grapheme nodes of the TLA network. The TLA network learns associations between spelling patterns and stress patterns through the training with a large database which might be analogous to human readers who learn implicit cues by a great deal of reading experience. Subsequently, a sensitivity for orthographic stress cues develops which allows for the generation of an adequate stress pattern when decoding printed polysyllabic words (Perry et al. 2010: 31f), irrespective of the bias towards the dominant stress pattern in the phonological output buffer. Accordingly, in the course of advances in reading development, the initial default stress assignment is more and more supplemented by metrical information which is quickly available from the sublexical pathway. We might assume that a reliable cue to word stress can alleviate the dominance effect (as provided by consistent word endings, such as –os in Kokos). Given that orthographic cues to word stress are available and processed by the reader, the model would predict that the dominance effect in words like *Kokos* is smaller than in words like *Tresor* lacking reliable stress cues. In other words, the model predicts a processing advantage for words with a stress consistent vs. inconsistent ending indicating that stress-to-spelling consistent words are easier to identify and/or that stress-to-spelling inconsistent words are related to processing difficulties in word reading. This prediction was borne out by the preliminary observations of Beyermann (unpublished manuscript). However, future investigations on word stress in German silent reading could shed more light on the developmental aspect of dominance and consistency effects.

Recent observations reported for other languages (e.g., Pagliuca & Monaghan 2009; Paizi, Zoccolotti & Burani 2011; and Sulpizio & Colombo 2013 for Italian; Arciuli et al. 2010 for English) support the view that in more experienced word reading the sublexical routine automatically relies on available stress cues which alleviate the dominance effect. This further implies that if implicit orthographic knowledge is the basis for the sensitivity to orthographic stress cues, the relative strength of the stress effects might crucially depend on the reading and spelling proficiency. This assumption is confirmed by empirical observations reported for other languages (e.g., for Greek by Protopapas & Gerakaki 2009; for Italian by Sulpizio & Colombo 2013), indicating that more experienced readers acquaint with orthographic cues to word stress due to growing proficiency in word reading. In the naming experiment reported by Sulpizio & Colombo, school children from grade 2 and 4 showed differences in their performances. Whereas the dominance effect on the error rates decreased with increasing age, the stress consistency had a growing impact on the reading performances with increasing age. In other words, the amendment of general probabilistic knowledge on lexical stress (which stress patterns are existent and how frequently do they occur) with implicit spelling knowledge on associations between spelling patterns and stress patterns might be thought of as a typical advancement in reading development.

Which are the relevant orthographic stress cues?

However, a number of further questions might be answered by future research. For one, more has to be learnt about the inventory of potential cues to lexical stress available during reading. In the relevant literature on lexical stress during word reading there is a consensus on the assumption that experienced readers gain implicit knowledge on potential cues to word stress provided by word spellings (e.g., Pagliuca & Monaghan 2009; Arciuli, et al. 2010; Perry et al. 2010; Paizi et al. 2011; see also Colombo 1991). However, it is as yet not well understood which spelling patterns provide reliable cues to word stress which are actually processed during word reading (there are only few thorough investigations on cues to lexical stress; e.g., Arciuli et al. 2010 for English), and in addition, the relevance of different cues might vary across languages. For German, the results of a recent word production study (Röttger et al. 2012) show that the orthographic complexity of the final syllable rime had an influence on which stress pattern was assigned. When the final syllable of a disyllabic word contained a more complex orthographic rime it was more likely to be stressed. From this observation the authors conclude that the orthographic weight of the final rime is one among other structural factors that determine which syllable receives the main stress. However, a broader basis of empirical evidence from different languages is required to understand which stress cues are potentially available during word reading and which of them are relevant (see e.g., Kelly et al. 1998; Rastle & Coltheart 2000; Jarmulowicz, Hay, Taran & Ethington 2008; Arciuli et al. 2010 on English; Colombo 1991; Cappa, Nespor, Ielasi, Miozzo 1997; Sulpizio & Colombo 2013 on Italian; Protopapas, Gerakaki & Alexandri 2006 on Greek; Gutiérrez-Palma & Palma-Reyes 2004 on Spanish; and Jouravlev & Lupker 2013 on Russian).

Given that there are multiple sources of stress cues during word reading (like orthographic syllable structure, word endings, or morphological cues) it seems difficult to consider all potential cues when constructing the stimulus material for an experiment. This might be the reason for a number of different observations reported in the literature on stress effects in word reading. For example, some studies report stress effects only in the accuracy data, whereas other studies detected stress effects in the latency data as well (for examples see e.g., Yap & Balota 2009). Moreover, some studies report a general stress consistency effect that interacts with the factor stress dominance (e.g., Burani & Arduino 2004) whereas other studies report a mirror image with a general dominance effect interacting with stress consistency (e.g., Jouravlev & Lupker 2013). Language-specific as well as item-specific factors may play a role for the occurrence of stress effects. Different item sets from the same language might yield different patterns of results (e.g., Perry, Ziegler & Zorzi 2014 on Italian). Interestingly, Jouravlev & Lupker (2013) found a stress dominance effect only in the responses to disyllabic Russian adjectives where initial stress is the predominant pattern, but not in verbs and nouns where both initial and final stress are distributed equally. The idea of a default stress assignment thus needs to be clarified with respect to the question when a stress pattern might be sufficiently dominant to be assigned as a default, pertaining to a certain class of words in the lexicon.

The findings reported in Jouravlev & Lupker point to another open issue. It is unclear whether any pattern of word stress is stored as part of the lexical entry (e.g., Perry et al. 2010) or whether only subdominant patterns are lexically stored (Levelt et al. 1999), and if so, which patterns are to be seen as dominant for when there are more than two options (like for example in German trisyllabic nouns which can be stressed on the first, second, or final syllable; compare e.g., *ˈSellerie, Karˈtoffel, Fantaˈsie* ‘celery, potato, fantasy’).For example, Röttger et al. (2012) argue for a different view on default stress patterns. In their pseudoword production study the authors report that none of the potential default stress patterns for a given structural condition was predominantly produced in more than 60% of the utterances. Therefore, it seems questionable whether a default pattern for trisyllabic words can be assumed, and consequently, any pattern of lexical stress might be stored in memory. However, even if we assume that any metrical information is lexically stored, this does not contradict the assumption that, if there is a dominant stress pattern for a class of words these words are prone to a default assignment. Note that in disyllabic German words first syllable stress clearly predominates, such that a default pattern might be assumed at least for disyllabic words (compare Study 1 and 2).

The empirical observations of Study 1 suggest that initial stress is assigned as a default pattern for German disyllabic nouns in young reading (as indicated by the dominance effect). The corpus study (Study 2) revealed that word endings provide potential orthographic cues to stress for disyllabic nouns which might be processed during German word reading. Young readers might lack implicit knowledge on stress cues provided by the word spellings, whereas skilled adult readers are predicted to be affected by the consistency of these stress cues. Altogether, these findings are in line with the view that lexical stress, a prosodic feature only implicitly encoded in print, is processed in German word reading across different stages of reading development.

In sum, the studies reported in Chapter 4 and 5 of this dissertation corroborate the view that lexical stress is involved in silent word reading, providing empirical evidence from German polysyllabic word identification in young readers. Hence, the data support the

Implicit Prosody Hypothesis (Fodor 1998, 2002) with further empirical evidence for an automatic generation of a prosodic contour during reading, which includes word-level prosody. For alphabetic languages like German it seems plausible that an automatic phonological activation generates an abstract representation of written words which is compositional, i.e., different levels of phonological representation are constructed in parallel (Morais 2003), including prosodic units like syllables and lexical stress.

The sensitivity to orthographic stress cues or the relative strength of the stress effects is assumed to depend on the reading proficiency (e.g., Arciuli et al. 2010). In other words, the amendment of general probabilistic knowledge on lexical stress (which stress patterns are existent and how frequently do they occur) with implicit spelling knowledge on associations between spelling patterns and stress patterns might be thought of as a typical advancement in reading development.

7.2 Orthography-phonology interaction

In light of the view that phonological information like word stress is automatically activated during written word processing (which might support the working memory), does orthographic information also play a role during auditory word processing? More precisely, this work aimed to shed light on the questions:

3. Does spelling knowledge influence spoken word processing? And does the influence of spelling knowledge on spoken word processing vary as a function of reading experience?

These questions were addressed by Study 3 reported in Chapter 6 (Beyermann & Penke 2014a). The results indicate that orthographic knowledge is involved in spoken word processing, and hence confirm the assumption that orthographic *and* phonological knowledge on words is automatically activated in spoken and written word identification.

Study 3 demonstrated that young readers as well as adult readers are influenced by spelling knowledge during spoken word identification. In the experiment, words with rimes associated with several spelling patterns (e.g., *Tier* ‘animal’ containing /iːɐ̯/ like in <wir> ‘we’; <ihr> ‘you(pl.)’; <Bier> ‘beer’) were accepted more slowly than words with rimes that are always spelled the same way in different words (e.g., *Ring* ‘ring’ containing /ɪŋ/ always spelled <ing>). This sound-to-spelling consistency effect indicates that spelling alternatives were co-activated during auditory word perception. A possible explanation for this observation might be that literate listeners automatically build up an abstract phonological representation that is based on available spelling knowledge to underpin the auditory working memory with additional and physically stable information on the speech input, which is otherwise only available for a short moment in time (Taft 2011). The availability of additional, supportive spelling information on the auditory input might contribute to the activation of candidate words during lexical search. If the spelling information is consistent, a more specific abstract representation can be activated as compared to auditory input that is associated with alternative spelling patterns in different words. It is conceivable that unambiguous spelling information is more supportive than inconsistent spelling information such that the more specific or the more quickly is the built-up of an abstract representation for a spoken word.

How do beginning readers learn word spellings? For words with many ‘friends’ sharing the same sound and the same spelling the correct spelling can be generated by productive phoneme-to-grapheme conversion rules, given that similarity patterns in the mental lexicon are the basis for such rules (e.g., Metsala 1997; Bybee & Hopper 2001, see Chapter 2.2.3). In a language with a high degree of orthographic transparency like German the word pronunciation can be easily generated by means of transparent spelling-to-sound relations. However, albeit the relatively transparent translation from spelling to sound, there is a considerable amount of variability in the sound-to-spelling translations in German words. The correct spellings for words with inconsistent sound-to-spelling patterns cannot be generated by simple sound-to-spelling translation rules, and probably need to be stored in memory (e.g., Klicpera et al. 2010). In order to memorize the correct spelling of orthographically irregular words additional mnemonics or explicit training is required (Treiman 1998). An integration of orthographic trainings in the primary grades is an educational standard in German (Schründer-Lenzen 2013: 211ff). Moreover, spelling knowledge is also learnt implicitly through repeated practice in word decoding (e.g., de Jong et al. 2009; see Chapter 2.2.2). Through reading and spelling practice, word recognition units are learnt which can be seen as typical spelling-sound patterns that allow for an identification of printed words. Contrary to our expectations, we found no evidence that orthographic effects were modulated by reading experience. The results of our experiment discussed in Chapter 6 show that beginning readers already from 2nd grade were influenced by sound-to-spelling consistency during spoken word processing, indicating that they processed lexically stored spelling information. In other words, young readers seem to memorize spelling patterns from an early stage on, i.e., spelling knowledge is incorporated in the mental lexicon already from the very beginning of literacy acquisition.

What is spelling knowledge good for? First, of course, in order to produce correct word spellings, a writer must know the correct spelling. But spelling knowledge is not only essential for producing correct word spellings; beyond that it is seen as a basic ingredient for a larger sight-vocabulary, the acquisition of word recognition units and thus, for an increase in the reading speed (see Chapter 2.2). Spelling patterns represent the sound units which constitute words and thus are assumed to promote the insight into the phonological and orthographic structure of words (compare Klicpera et al. 2010). Another beneficial effect of implicit and explicit orthographic learning is that word spellings make a shared morphological origin visible which might otherwise remain undetected due to reduction processes in spoken language (e.g., *Fernseher* 'TV' often reduced to a disyllabic word [fɛɐ̯nzɛɐ] and *sehen* often pronounced as one syllable [ze:n] 'to see, to view, to watch', Röber 2010). In light of the findings from Study 2 (Chapter 5), it might be assumed that implicit spelling knowledge is helpful for predicting the stress pattern of polysyllabic words during reading. And the experimental observations discussed in Study 3 emphasize the role of spelling knowledge for literacy acquisition by showing its supportive function during *spoken* word processing already in the early grades. According to the *Lexical Constituency Model* (Perfetti & Liu 2006) the identification of a printed word is associated with the access to stored information on that word (spelling information, pronunciation, word meaning) which are highly interlocked in proficient readers, whereas they are less specific and less connected in younger or less skilled readers (e.g., Landerl et al. 1996). When spelling information on word forms is acquired this increases the visibility of phonemic content, and creates redundancy (from orthography to the same phonological information stored in the lexicon). Proponents of the Lexical Restructuring Hypothesis propose that the restructuring of stored phonological word forms from coarse-grained, less specific to more fine-grained, phoneme-based representations is also driven by acquired orthographic information (see e.g., Ziegler & Goswami 2005; compare Chapter 2.2.3). Broadly speaking, the acquisition of spelling knowledge is assumed to improve the quality of word representations in the mental lexicon.

In order to allow for these supportive effects of spelling knowledge, teaching instructions in early reading should incorporate explicit as well as implicit spelling instructions (see also e.g., Graham 2000; Treiman 1998; Klicpera et al. 2010). However, in Germany the choice of which tuition method is applied in the primary grades rests with the individual schools and teachers. And in the 90ies, a method developed by Reichen (e.g., Reichen 2001; henceforth called the *Reichen Method*) has spread across a number of primary schools in different regions of Germany. This method does neither include a training of word decoding strategies, nor does it consider the acquisition of correct word spellings in beginning readers, at least in grade one. The instructions for children learning to read with the Reichen Method focus on the acquisition of sound-letter correspondences through producing creative texts. Assisted by a comprehensive table that lists sound-to-spelling correspondences, each learner is encouraged to write by segmenting spoken words into phonetic units, translating them to letters, and writing them down. One advantage of this approach might be that spelling poses fewer demands on the auditory working memory than reading: As soon as the first or a following component sound unit is identified and converted to a letter, it can be written down and the next sound unit can be focused. Only few units need to be retained at once (e.g., Treiman 1998). That is, the children first focus on word spelling as an easier task than word decoding. The main goal of this teaching method is that the young learners understand the alphabetic principle by exploring and training sound-letter translations. Through creative spelling tasks they learn to produce written forms that express the phonetic content of words. However, no explicit training in word decoding strategies is given, which is seen as an essential help for poor readers (Scheerer-Neumann 1981; Schründer-Lenzen 2013). Moreover, since repeated practice in word reading helps to memorize the correct word spellings, word reading strategies should be an integral part of the tuitions. Another major disadvantage of the Reichen Method is that the successful conversion from spoken words to letter strings requires the children to know the exact sound form of words, i.e., to be familiar with the pronunciation (this puts children with German as a second language in disadvantage) and to be able to analyze spoken words in appropriate pronunciation units (this puts children with difficulties in phonological processing in disadvantage). For a more detailed critique of the Reichen Method, see e.g., Schründer-Lenzen (2007, 2013). Fortunately, teachers employing the Reichen Method usually apply supplemental methods (Schründer-Lenzen 2013), and follow the recommendation of the educational standards by including implicit and explicit orthographic trainings.

The orthographic effects found in spoken word processing and the role of prosodic properties in visual word processing point to the close link between the written and the spoken modality in literate speakers. Reading development promotes the sensitivity for the phonological structure of language by making it visible and thus providing a stable representation. The reported results indicate that orthographic *and* phonological knowledge on words is automatically activated during word processing in both modalities (auditory and visual perception). The acquisition of highly specific orthographic knowledge hence seems to improve not only the ability to learn new words and read familiar words, but might as well facilitate the auditory word identification process. In sum, learning to read does not only afford the young learner to approach a higher education, but changes the way language is perceived.

References

Anthony, J. L., & Lonigan, C. J. (2004). The Nature of Phonological Awareness: Converging Evidence From Four Studies of Preschool and Early Grade School Children. *Journal of Educational Psychology*, *96*(1), 43.

Arciuli, J., Monaghan, P., & Seva, N. (2010). Learning to assign lexical stress during reading aloud: Corpus, behavioral, and computational investigations. *Journal of Memory and Language*, *63*(2), 180-196.

Aro, M., & Wimmer, H. (2003). Learning to read: English in comparison to six more regular orthographies. *Applied Psycholinguistics*, *24*(04), 621-635.

Ashby, J. (2006). Prosody in skilled silent reading: Evidence from eye movements. *Journal of Research in Reading*, *29*(3), 318-333.

Ashby, J., & Clifton, C. (2005). The prosodic property of lexical stress affects eye movements in silent reading. *Cognition* 96(3): B89–100.

Baayen, R. H., Piepenbrock, R., & van Rijn, H. (1993). *The CELEX lexical database.* Philadelphia, University of Pennsylvania. Linguistic Data Consortium.

Baddeley, A., Eldridge, M., & Lewis, V. (1981). The role of subvocalisation in reading. *The Quarterly Journal of Experimental Psychology*, *33*(4), 439-454.

Balota, D. A. (1994). Visual Word Recognition. The Journey From Features to Meaning. In M. A. Gernsbacher (Ed.), *Handbook of Psycholinguistics* (pp 303-358). NY: Academic Press.

Beyermann, S. (2013). Orthographic cues to word stress in German: Word endings and number of final consonant letters. *Written Language and Literacy*, 16(1), 32-59. DOI: 10.1075/wll.16.1.02bey

Beyermann, S., & Penke, M. (2014a). The impact of orthographic consistency on German spoken word identification. *International Journal of Disability, Development and Education*, 61(3), 212-224. DOI: 10.1080/1034912X.2014.932564

Beyermann, S., & Penke, M. (2014b). Word stress in German single-word reading. *Reading Psychology*, 35(6), 577-600. DOI 10.1080/02702711.2013.790325

Bijeljac-Babic, R., Millogo, V., Farioli, F., & Grainger, J. (2004). A developmental investigation of word length effects in reading using a new on-line word identification paradigm. *Reading and Writing*, *17*(4), 411-431.

Black, M., & Byng, S. (1986). Prosodic constraints on lexical access in reading. *Cognitive Neuropsychology*, *3*(4), 369-409.

Borgwaldt, S., Hellwig, F., & de Groot, A. (2004). Word-initial entropy in five languages. *Written Language and Literacy* 7: 165-184.

Bourassa, D. C., & Treiman, R. (2008). Morphological constancy in spelling: A comparison of children with dyslexia and typically developing children. *Dyslexia*, *14*(3), 155-169.

Brandenburger, N., & Klemenz, A. (2009). *Lese-Rechtschreib-Störungen: eine modellorientierte Diagnostik mit Therapieansatz*. Elsevier, Urban & Fischer Verlag.

Bruck, M. (1992). Persistence of dyslexics' phonological awareness deficits. *Developmental psychology*, *28*(5), 874.

Burani, C., & Arduino, L. S. (2004). Stress regularity or consistency? Reading aloud Italian polysyllables with different stress patterns. *Brain and Language*, *90*(1), 318-325.

Bußmann, H. (2002). *Lexikon der Sprachwissenschaft* (Vol. 452). Stuttgart: Kröner.

Butterworth, B. (1983). Lexical representations. In B. Butterworth (Ed.): *Language production*, *Vol. 2*: *Development, Writing and Other Language Processes*. London: Academic Press: 257-294.

Bybee, J. L., & Hopper, P. J. (Eds.). (2001). *Frequency and the emergence of linguistic structure* (Vol. 45). John Benjamins Publishing.

Cappa, S. F., Nespor, M., Ielasi, W., & Miozzo, A. (1997). The representation of stress: evidence from an aphasic patient. *Cognition*, *65*(1), 1-13.

Carroll, J. M., & Snowling, M. J. (2001). The effects of global similarity between stimuli on children's judgments of rime and alliteration. *Applied Psycholinguistics*, *22*, 327–342.

Cholin, J., Levelt, W. J., & Schiller, N. O. (2006). Effects of syllable frequency in speech production. *Cognition*, *99*(2), 205-235.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences.* Hillsdale, N.J.; Erlbaum.

Colombo, L. (1991). The role of lexical stress in word recognition and pronunciation. *Psychological Research* 53: 71-79.

Colombo, L., & Tabossi, P. (1992). Strategies and stress assignment: Evidence from a shallow orthography. *Advances in psychology*, *94*, 319-340.

Coltheart, M. (2006). Dual route and connectionist models of reading: An overview. *London Review of Education*, 4, 5-17.

Coltheart, M., Curtis, B., Atkins, P., & Haller, M. (1993). Models of reading aloud: Dual-route and parallel-distributed-processing approaches. *Psychological review*, *100*(4), 589.

Coltheart, M., & K. Rastle (1994). Serial processing in reading aloud: evidence for dual-route models of reading. In *Journal of Experimental Psychology: Human Perception and Performance* 20(6): pp 1197-1211.

Coltheart, M., Rastle, K., Perry, C., Langdon, R., & Ziegler, J. (2001). DRC: a dual route cascaded model of visual word recognition and reading aloud. *Psychological review*, *108*(1), 204.

Conrad, M., & Jacobs, A. M. (2004). Replicating syllable frequency effects in Spanish in German: One more challenge to computational models of visual word recognition. *Language & Cognitive Processes*, 19, 369-390.

Cossu, G., Rossini, F., & Marshall, J. C. (1993). When reading is acquired but phonemic awareness is not: A study of literacy in Down's syndrome. *Cognition*, *46*(2), 129-138.

Coulmas, F. (1989). *The writing systems of the world*. Oxford: Blackwell.

Cutler, A. (2005). The lexical statistics of word recognition problems caused by L2 phonetic confusion. In *Interspeech* (pp. 413-416).

Daneman, M., & Reingold, E. M. (1993). What eye fixations tell us about phonological recoding during reading. *Canadian Journal of Experimental Psychology/Revue canadienne de psychologie expÃ© rimentale*, *47*(2), 153.

Daneman, M., & Reingold, E. M. (2000). Do readers use phonological codes to activate word meanings? Evidence from eye movements. *Reading as a perceptual process*, 447-473.

de Jong, P. F., Bitter, D. J., van Setten, M., & Marinus, E. (2009). Does phonological recoding occur during silent reading, and is it necessary for orthographic learning?. *Journal of experimental child psychology*, *104*(3), 267-282.

Dieling, H., & Hirschfeld, U. (2002). Deutsch. In Hirschfeld, U., Kelz, H. P.& U. Müller (Eds.) *Phonetik international. Grundwissen von Afrikaans bis Zulu. Kontrastive Studien für Deutsch als Fremdsprache*, (2002 ff.). Retrieved from [www.phonetik-international.de; 09.10.2008]

Downing, J., & Valtin, R. (1984) *Language awareness and learning to read*. New York: Springer

Ehri, L. C. (1992). Reconceptualizing the development of sight word reading and its relationship to recoding. In Gough, P. B., Ehri, L.C. & Treiman, R. (Eds) *Reading acquisition*, 1992 pp. 107-143. Hillsdale, NJ, England: Lawrence Erlbaum Associates.

Ehri, L. C. (1995). Phases of development in learning to read words by sight. *Journal of Research in Reading,* 18(2), 116-125.

Ehri, L. C. (1998). Grapheme—Phonerne Knowledge Is Essential for Learning to Read Words in English. *Word recognition in beginning literacy*, 1.

Fodor, J. D. (1998). Learning to parse? *Journal of Psycholinguistic Research*, 27, 285-319.

Fodor, J. D. (2002). Prosodic disambiguation in silent reading. In *Proceedings-NELS*, Vol. 1, No. 32(1): pp. 113-132.

Frith, U. (1985). Beneath the surface of developmental dyslexia. In K. E. Patterson, J.C. Marshall, & M. Coltheart (Eds.) *Surface dyslexia: Neuropsychological and cognitive studies of phonological reading* (pp. 301-330).

Frith, U., Wimmer, H., & Landerl, K. (1998). Differences in phonological recoding in German-and English-speaking children. *Scientific Studies of Reading*, *2*(1), 31-54.

Frost, R. (1998). Toward a Strong Phonological Theory of Visual Word Recognition: True Issues and False Trails. In *Psychological Bulletin* 121(1): pp 71-99.

Frost, R. (2012). Towards a universal model of reading. *Behavioral and Brain Sciences*, 35(5), 263–329. doi:10.1017/S0140525X11001841

Frost, R., Katz, L., & Bentin, S. (1987). Strategies for visual word recognition and orthographic depth: a multilingual comparison. *Journal of Experimental Psychology: Human Perception and Performance* 13: 104-15.

Frost, R., & Katz, L. (1992). The reading process is different for different orthographies: The orthographic depth hypothesis. *Orthography, phonology, morphology and meaning*, 94, 67-84.

Frost, R., Forster, K. I., & Deutsch, A. (1997). What can we learn from the morphology of Hebrew? A masked-priming investigation of morphological representation. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *23*(4), 829.

Giegerich, H. J. (1992). *English phonology: An introduction*. Cambridge University Press.

Glushko, R. J. (1979). The organization and activation of orthographic knowledge in reading aloud. *Journal of experimental psychology: Human perception and performance*, *5*(4), 674.

Goswami, U., Ziegler, J. C., Dalton, L., & Schneider, W. (2001). Pseudohomophone effects and phonological recoding procedures in reading development in English and German. *Journal of Memory and Language 45:* 648–664.

Goswami, U., Ziegler, J. C., Dalton, L., & Schneider, W. (2003). Nonword reading across orthographies: How flexible is the choice of reading units? *Applied Psycholinguistics* 24(2): 235-247.

Goswami, U., Ziegler, J. C., & Richardson, U. (2005). The effects of spelling consistency on phonological awareness: A comparison of English and German. *Journal of experimental child psychology*, *92*(4), 345-365.

Gough, P. B., & Tunmer, W. E. (1986). Decoding, reading, and reading disability. *Remedial and Special Education*, *7*(1), 6-10.

Goulden, R., Nation, P., & Read, J. (1990). How large can a receptive vocabulary be?. *Applied Linguistics, 11*(4), 341-363.

Graham, S. (2000). Should the natural learning approach replace spelling instruction?. *Journal of Educational Psychology*, *92*(2), 235.

Grainger, J., Kiyonaga, K., & Holcomb, P. J. (2006). The time course of orthographic and phonological code activation. *Psychological Science*, *17*(12), 1021-1026.

Grainger, J., Lété, B., Bertand, D., Dufau, S., & Ziegler, J. C. (2012). Evidence for multiple routes in learning to read. *Cognition*, *123*(2), 280-292.

Gussenhoven, C. (1992). Dutch. *Journal of the International Phonetic Association*, *22*(1-2), 45-47.

Gutiérrez-Palma, N., & Palma-Reyes, A. (2004). Lexical stress and reading: a study with children. *Electronic Journal of Research in Educational Psychology* 2(2): 143-160.

Hammond, M. (1997). Vowel quantity and syllabification in English. *Language*, 1-17.

Ho, C. S. H., & Bryant, P. (1997). Learning to read Chinese beyond the logographic phase. *Reading Research Quarterly*, *32*(3), 276-289.

Hoover, W. A., & Gough, P. B. (1990). The simple view of reading. *Reading And Writing: An Interdisciplinary Journal*, 2,127–160.

Huang, H. S., & Hanley, J. R. (1994). Phonological awareness, visual skills and Chinese reading acquisition in first graders: A longitudinal study in Taiwan. *Advances in the study of Chinese language processing*, *1*, 325-342.

Hulme, C., & Snowling, M. J. (2014). The interface between spoken and written language: developmental disorders. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *369*(1634), 20120395.

Hung, D. L., & Tzeng, O. J. (1981). Orthographic variations and visual information processing. *Psychological Bulletin*, *90*(3), 377.

Hurrelmann, B. (2004). Sozialisation der Lesekompetenz. In *Struktur, Entwicklung und Förderung von Lesekompetenz* (pp. 37-60). VS Verlag für Sozialwissenschaften.

Inhoff, A. W., & Topolski, R. (1994). Use of phonological codes during eye fixations in reading and in on-line and delayed naming tasks. *Journal of Memory and Language*, *33*(5), 689-713.

Janßen, U. (2004). *Untersuchungen zum Wortakzent im Deutschen und Niederländischen* [*Investigations on word stress in German and Dutch*] (Doctoral dissertation). University of Düsseldorf, Düsseldorf, Germany

Jarmulowicz, L., Hay, S. E., Taran, V. L., & Ethington, C. A. (2008). Fitting derivational morphophonology into a developmental model of reading. *Reading and Writing*, *21*(3), 275-297.

Jessen, M. (1993). Stress conditions on vowel quality and quantity in German. (Working papers of the Cornell Phonetics Laboratory, Vol. 8, pp.1-27).

Jorm, A. F., & Share, D. L. (1983). An invited article: Phonological recoding and reading acquisition. *Applied Psycholinguistics*, *4*(02), 103-147.

Joshi, R. M., & Aaron, P. G. (2000). The component model of reading: Simple view of reading made a little more complex. *Reading Psychology*, *21*(2), 85-97.

Jouravlev O., & Lupker, S. J. (2013). Stress consistency and stress regularity effects in Russian. *Language and Cognitive Processes*. DOI: 10.1080/01690965.2013.81356

Jun, S. A. (2003). Prosodic phrasing and attachment preferences. *Journal of Psycholinguistic Research*, *32*(2), 219-249.

Katz, L., & Frost, S. J. (2001). Phonology constrains the internal orthographic representation. *Reading and Writing*, *14*(3-4), 297-332.

Kelly, M. H., Morris, J., & Verrekia, L. (1998). Orthographic cues to lexical stress: Effects on naming and lexical decision. In *Memory & Cognition* 26(4): 822-832.

Kenstowicz, M. J. (1994). *Phonology in generative grammar*. Cambridge, MA: Blackwell.

Klicpera, C., Gasteiger-Klicpera, B., & Schabmann, A. (1993). Lesen und Schreiben – Entwicklung und Schwierigkeiten: Die Wiener Längsschnittuntersuchungen über die Entwicklung, den Verlauf und die Ursachen von Lese- und Rechtschreibschwierigkeiten in der Pflichtschulzeit. Huber, Bern.

Klicpera, C., Schabmann, A., & Gasteiger-Klicpera, B. (2010). *Legasthenie–LRS–Modelle, Diagnose, Therapie und Förderung*. Reinhardt, München.

Landerl, K. (2000). Influences of orthographic consistency and reading instruction on the development of nonword reading skills. *European Journal of Psychology of Education*, *15*(3), 239-257.

Landerl, K., Frith, U., & Wimmer, H. (1996). Intrusion of orthographic knowledge on phoneme awareness: Strong in normal readers, weak in dyslexic readers. Applied Psycholinguistics, 17: pp. 1-14.

Landerl, K., Wimmer, H., & Frith, U. (1997). The impact of orthographic consistency on dyslexia: A German-English comparison. *Cognition*, *63*(3), 315-334.

Landerl, K., & Wimmer, H. (2008). Development of word reading fluency and spelling in a consistent orthography: An 8-year follow-up. *Journal of Educational Psychology*, *100*(1), 150.

Landerl, K., Ramus, F., Moll, K., Lyytinen, H., Leppänen, P. H., Lohvansuu, K., [...] & Schulte-Körne, G. (2013). Predictors of developmental dyslexia in European orthographies with varying complexity. *Journal of Child Psychology and Psychiatry*, *54*(6), 686-694.

Levelt, W. J. (1992). Accessing words in speech production: Stages, processes and representations. *Cognition*, *42*(1), 1-22.

Levelt, W. J. M., A. Roelofs, & Meyer, A. S. (1999). A theory of lexical access in speech production. *Behavioral and Brain Sciences* 22: 1-38.

Liberman, M. Y., & Prince, A. S. (1977). On stress and linguistic rhythm. In *Linguistic Inquiry*, 8: pp. 249-336.

Liberman, I. Y., & Shankweiler, D. (1985). Phonology and the problems of learning to read and write. *Remedial and special education*, *6*(6), 8-17.

Lindgren, S. D., De Renzi, E., & Richman, L.C. (1985). Cross-national comparisons of developmental dyslexia in Italy and the United States. *Child development*, 1404-1417.

Marian, V., Bartolotti, J., Chabal, S., & Shook, A. (2012). CLEARPOND: Cross-linguistic easy-access resource for phonological and orthographic neighborhood densities. *PloS one*, *7*(8), e43230.

Marinus, E., & de Jong, P. F. (2008). The use of sublexical clusters in normal and dyslexic readers. *Scientific Studies of Reading*, *12*(3), 253-280.

Martinet, C., Valdois, S., & Fayol, M. (2004). Lexical orthographic knowledge develops from the beginning of literacy acquisition. *Cognition*, *91*(2), B11-B22.

Mattingly, I. G. (1984). Reading, linguistic awareness, and language acquisition. In *Language awareness and learning to read* (pp. 9-25). Springer New York.

Mattingly, I. G. (1992). Linguistic awareness and orthographic form. *Advances in psychology*, *94*, 11-26.

Metsala, J. L. (1997). Spoken word recognition in reading disabled children. *Journal of Educational Psychology*, *89*(1), 159.

Miller, G. A., & Friedman, E. A. (1957). The reconstruction of mutilated English texts. *Information and Control*, *1*(1), 38-55.

Morais, J. (2003). Levels of phonological representation in skilled reading and in learning to read. *Reading and Writing*, *16*(1-2), 123-151.

Morais, J., Cary, L., Alegria, J., & Bertelson, P. (1979). Does awareness of speech as a sequence of phones arise spontaneously?. *Cognition*, *7*(4), 323-331.

Morais, J., & Mousty, P. (1992). The causes of phonemic awareness. In Alegria, J., Holender, D. J., Morais, J., Radeau, M. (Eds) *Analytic approaches to human cognition*, 1992. pp. 193-212. Oxford, England: North-Holland.

Muter, V., Hulme, C., Snowling, M. J., & Stevenson, J. (2004). Phonemes, rimes, vocabulary, and grammatical skills as foundations of early reading development: evidence from a longitudinal study. *Developmental psychology*, *40*(5), 665.

Naumann, J., Artelt, C., Schneider, W., & Stanat, P. (2010). Lesekompetenz von PISA 2000 bis PISA 2009. Klieme, Eckhard et al (eds.), *PISA 2009. Bilanz nach einem Jahrzehnt. Münster: Waxmann, 2010,* p. 23-71. retrieved 10/03/2014 from [www.pedocs.de/volltexte/2011/3530/pdf/Naumann_et.Al_Lesekompetenz_D_A.pdf]

Neef, M. (2004). The relation of vowel letters to phonological syllables in English and German. *Written Language and Literacy* 7(2): 205-234.

Neef, M. (2005). *Die Graphematik des Deutschen*. Tübingen: Niemeyer.

Olson, D.R. (1993). How writing represents speech. Language & Communication 13(1), 1-17.

Paizi, D., Zoccolotti P., & Burani, C. (2011). Lexical stress assignment in Italian developmental dyslexia. *Reading and Writing* 24: 443-461.

Pagliuca, G., & Monaghan, P. (2009). A connectionist model of reading for Italian. In: Connectionist models of behaviour and cognition II : proceedings of the 11th Neural Computation and Psychology Workshop, University of Oxford, UK, 16-18 July 2008. WORLD SCIENTIFIC PUBL CO PTE LTD, Singapore, pp. 301-311.

Paulesu, E., McCrory, E., Fazio, F., Menoncello, L., Brunswick, N., Cappa, S. F., [...] & Frith, U. (2000). A cultural effect on brain function. *Nature neuroscience*, *3*(1), 91-96.

Paulesu, E., Démonet, J. F., Fazio, F., McCrory, E., Chanoine, V., Brunswick, N., [...] & Frith, U. (2001). Dyslexia: cultural diversity and biological unity. *Science*, *291*(5511), 2165-2167.

Penke, M., & Schrader, K. (2008). The role of phonology in visual word recognition: Reading acquisition vs. skilled reading. *Written Language and Literacy* 11(2): 167-190.

Perre, L., Bertrand, D., & Ziegler, J. C. (2011). Literacy affects spoken language in a non-linguistic task: an ERP study. *Frontiers in psychology, 2*.

Perfetti, C. A. (1992). The representation problem in reading acquisition. In Gough, P. B., Ehri, L.C. & Treiman, R. (Eds) *Reading acquisition*, 1992 pp. 107-143. Hillsdale, NJ, England: Lawrence Erlbaum Associates.

Perfetti, C.A. (2001). Reading skills. In N. J. Smelser & P. B. Baltes (Eds.) International encyclopedia of the social & behavioral sciences (pp. 12800-12805). Oxford: Pergamon.

Perfetti, C. A. (2003). The universal grammar of reading. *Scientific Studies of Reading*, 7(1), 3-24.

Perfetti, C. A. (2007). Reading ability: Lexical quality to comprehension. *Scientific studies of reading*, *11*(4), 357-383.

Perfetti, C. A. (2011). Reading processes and reading problems: Progress toward a universal reading science. In P. McCardle, J. Ren, O. Tzeng, & B. Miller (Eds.), *Dyslexia across languages: Orthography and the brain-gene-behavior link* (pp. 18-32). Baltimore, MD: Brookes.

Perfetti, C.A., Beck, I. Bell, L.C. & C. Hughes (1987). Phonemic knowledge and learning to read are reciprocal: A longitudinal study of first grade children. *Merill-Palmer Quarterly* 33(3): 283-319.

Perfetti, C. A., Zhang, Z. & Berent, I. (1992). Reading in English and Chinese: Evidence for a" universal" phonological principle. In Frost, R., & Katz, L. (Eds.) *Orthography, phonology, morphology and meaning*. Advances in Psychology, 94. Amsterdam: Elsevier, 227-248.

Perfetti, C. A., & Hart, L. (2001). The lexical basis of comprehension skill. In Gorfein, David S. (Ed), (2001). *On the consequences of meaning selection: Perspectives on resolving lexical ambiguity*, 2001, pp. 67–86. Washington, DC: American Psychological Association.

Perfetti, C. A., & Liu, Y. (2005). Orthography to phonology and meaning: Comparisons across and within writing systems. *Reading and Writing*, *18*(3), 193-210.

Perfetti, C. A., & Liu, Y. (2006). Reading Chinese characters: Orthography, phonology, meaning, and the Lexical Constituency Model. In P.Li, L.H. Tan, E. Bates, & O.J.L. Tzeng (Eds.), *The handbook of East Asian psycholinguistics, Vol. 1: Chinese* (pp.225-236). New York: Cambridge University Press.

Perfetti, C. A., & Dunlap, S. (2008). Universal principles and writing system variations in learning to read. *Learning to read across languages. Mahwah, NJ: Erlbaum*.

Perfetti, C. A., Cao, F., & Booth, J. (2013). Specialization and universals in the development of reading skill: How Chinese research informs a universal science of reading. *Scientific Studies of Reading*, *17*(1), 5-21.

Perry, C., Ziegler, J. C., & Zorzi, M. (2007). Nested incremental modeling in the development of computational theories: the CDP+ model of reading aloud. *Psychological Review*, *114*(2), 273.

Perry, C., Ziegler, J. C., Braun, M., & Zorzi, M. (2010). Rules versus statistics in reading aloud: New evidence on an old debate. *European Journal of Cognitive Psychology*, 22(5), 798-812. doi http://dx.doi.org/10.1080/09541440902978365

Perry, C., Ziegler, J. C., & Zorzi, M. (2010). Beyond single syllables: Large scale modeling of reading aloud with the Connectionist Dual Process (CDP++) model. *Cognitive Psychology*, 61(2): 106-151.

Perry, C., Ziegler, J. C., & Zorzi, M. (2014). CDP++. Italian: Modelling sublexical and supralexical inconsistency in a shallow orthography. *PloS one*, *9*(4), e94291.

Plaut, D. C., McClelland, J. L., Seidenberg, M. S., & Patterson, K. (1996). Understanding normal and impaired word reading: computational principles in quasi-regular domains. *Psychological review*, *103*(1), 56.

Pollatsek, A., Lesch, M., Morris, R. K., & Rayner, K. (1992). Phonological codes are used in integrating information across saccades in word identification and reading. *Journal of Experimental Psychology: Human Perception and Performance*, *18*(1), 148.

Protopapas, A., Gerakaki, S. & Alexandri, S. (2006). Lexical and default stress assignment in reading Greek. *Journal of Research in Reading*, 29(4): 418-432.

Protopapas, A., & Gerakaki, S. (2009). Development of processing stress diacritics in reading Greek. *Scientific Studies of Reading*, *13*(6), 453-483.

Rapp, B., Folk, J. R., & Tainturier, M. (2000). *Word Reading. In The handbook of cognitive neuropsychology. What deficits reveal about the human mind, Rapp, B. (ed.), pp 233-262. Philadelphia: Psychology Press.*

Rastle, K., & Coltheart, M. (2000). Lexical and nonlexical print-to-sound translation of disyllabic words and nonwords. *Journal of Memory and Language*, 42: 342–364.

Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychological bulletin*, *124*(3), 372.

Reichen, J. (2001). *Lesen durch Schreiben*. Heinevetter-Verlag.

Röber, C. (2008). Die Nutzung der phonologischen Informationen der Orthographie für das Lesen deutscher Wörter. Zur Problematik des Leseunterrichts in der Schule. Ms., Pädagogische Hochschule Freiburg.

Röber, C. (2010). Warum Erwachsene die Schriftbrille absetzen müssen. [Why adults have to put off the literacy-spectacles]. *Grundschule Deutsch*, 27, 7-10.

Röttger, T. B., Domahs, U., Grande, M., & Domahs, F. (2012). Structural factors affecting the assignment of word stress in German. *Journal of Germanic Linguistics*, *24*(01), 53-94.

Rozin, P., & Gleitman, L.R (1977). The structure and acquisition of reading II: The reading process and the acquisition of the alphabetic principle. In A. Reber & D. Scarborough (Eds.), *Toward a Psychology of Reading. 1977,* Hillsdale, N.J.: Erlbaum Associates.

Sampson, G. (1985). *Writing systems: A linguistic introduction*. Stanford, CA: Stanford University Press.

Schabmann, A., Schmidt, B. M., Klicpera, C., Gasteiger-Klicpera, B., & Klingebiel, K. (2009). Does systematic reading instruction impede prediction of reading a shallow orthography. *Psychology Science Quarterly*, *51*(3), 315-338.

Scheerer, E. (1987). *Visual word recognition in German*. Academic Press.

Scheerer-Neumann, G. (1981): The Utilization of Intraword Structure in poor Readers: Experimental Evidence and a Training Program. *Psychological Research*, 43, 155-178.

Schiff, R., & Ravid, D. (2004). Vowel representation in written Hebrew: Phonological, orthographic and morphological contexts. *Reading and Writing*, *17*(3), 241-265.

Schneider, W., Küspert, P., Roth, E., Visé, M., & Marx, H. (1997). Short-and long-term effects of training phonological awareness in kindergarten: Evidence from two German studies. *Journal of Experimental Child Psychology*, *66*(3), 311-340.

Schöler, H., Welling, A., Borchert, J., & Goetze, H. (Eds.). (2007). *Sonderpädagogik der Sprache*. Hogrefe, Göttingen.

Schründer-Lenzen, A. (2007). *Schriftspracherwerb und Unterricht: Bausteine professionellen Handlungswissens*, Springer Fachmedien, Wiesbaden.

Schründer-Lenzen, A. (2013). *Schriftspracherwerb*. Springer Fachmedien, Wiesbaden.

Seidenberg, M. S. (1985). Constraining models of word recognition. *Cognition*, *20*(2), 169-190.

Seidenberg, M. S., & McClelland, J. L. (1989). A distributed, developmental model of word recognition and naming. *Psychological review*, *96*(4), 523.

Seidenberg, M. S., & Gonnerman, L. M. (2000). Explaining derivational morphology as the convergence of codes. *Trends in cognitive sciences*, *4*(9), 353-361.

Seymour, P. H., Aro, M., & Erskine, J. M. (2003). Foundation literacy acquisition in European orthographies. *British Journal of psychology*, *94*(2), 143-174.

Share, D. L. (1995). Phonological recoding and self-teaching:< i> sine qua non</i> of reading acquisition. *Cognition*, *55*(2), 151-218.

Share, D. L. (1999). Phonological recoding and orthographic learning: A direct test of the self-teaching hypothesis. *Journal of experimental child psychology*, *72*(2), 95-129.

Share, D. L. (2004). Orthographic learning at a glance: On the time course and developmental onset of self-teaching. *Journal of experimental child psychology*, *87*(4), 267-298.

Share, D. L. (2008). On the Anglocentricities of current reading research and practice: the perils of overreliance on an" outlier" orthography. *Psychological bulletin*, *134*(4), 584.

Share, D. L., & Blum, P. (2005). Syllable splitting in literate and preliterate Hebrew speakers: Onsets and rimes or bodies and codas? *Journal of Experimental Child Psychology*, *92*(2), 182-202.

Shimron, J. (1993). The role of vowels in reading: A review of studies of English and Hebrew. *Psychological Bulletin, 114*(1), 52.

Sprenger-Charolles, L., Siegel, L. S., Béchennec, D., & Serniclaes, W. (2003). Development of phonological and orthographic processing in reading aloud, in silent reading, and in spelling: A four-year longitudinal study. *Journal of Experimental Child Psychology*, 84(3), 194-217.

Stanovich, K. E. (1982). Individual differences in the cognitive processes of reading I: Word decoding. *Journal of Learning Disabilities, 15,* 485-493.

Stenneken, P., Conrad, M., & Jacobs, A. M. (2007). Processing of syllables in production and recognition tasks. *Journal of Psycholinguistic Research*, *36*(1), 65-78.

Stuart, M., & Coltheart, M. (1988). Does reading develop in a sequence of stages? *Cognition*, *30*(2), 139-181.

Sulpizio, S. & Colombo, L. (2013). Lexical stress, frequency, and stress neighborhood effects in the early stages of Italian reading development. *The Quarterly Journal of Experimental Psychology*. doi: 10.1080/17470218.2013.785577.

Taft, M. (2011). Orthographic influences when processing spoken pseudowords: theoretical implications. *Frontiers in psychology*, *2*.

Taft, M., & Forster, K. I. (1975). Lexical storage and retrieval of polymorphemic and polysyllabic words. *Journal of Verbal Learning and Verbal Behavior 1*4: 638-647.

Taft, M., & Van Graan, F. (1998). Lack of phonological mediation in a semantic categorization task. *Journal of memory and language*, *38*(2), 203-224.

Tranel, B. (1987). *The sounds of French: An introduction*. Cambridge University Press.

Treiman, R. (1998). Why spelling? The benefits of incorporating spelling into beginning reading instruction. *Word recognition in beginning literacy*, 289-313.

Treiman, R., & Zukowski, A. (1990). Toward an understanding of English syllabification. *Journal of Memory and Language*, *29*(1), 66-85.

Valtin, R. (2010). Phonologische Bewusstheit: eine notwendige Voraussetzung beim Lesen-und Schreibenlernen? *LOGOS interdisziplinär*, *18*(1), 4.

Van Orden, G. C. (1987). A ROWS is a ROSE: Spelling, sound, and reading. *Memory & Cognition*, *15*(3), 181-198.

Ventura, P., Morais, J., Pattamadilok, C., & Kolinsky, R. (2004). The locus of the orthographic consistency effect in auditory word recognition. *Language and Cognitive Processes*, *19*(1), 57-95.

Ventura, P., Kolinsky, R., Fernandes, S., Querido, L., & Morais, J. (2007). Lexical restructuring in the absence of literacy. *Cognition*, *105*(2), 334-361.

Ventura, P., Morais, J., & Kolinsky, R. (2007). The development of the orthographic consistency effect in speech recognition: From sublexical to lexical involvement. *Cognition*, *105*(3), 547-576.

Verhoeven, L., & van Leeuwe, J. (2008). Prediction of the development of reading comprehension: a longitudinal study. *Applied Cognitive Psychology*, *22*(3), 407–423. doi: 10.1002/acp.1414

Verhoeven, L., Reitsma, P., & Siegel, L. S. (2011). Cognitive and linguistic factors in reading acquisition. *Reading and writing*, *24*(4), 387-394.

Wang, M., Koda, K., & Perfetti, C. A. (2004). Language and writing systems are both important in learning to read: A reply to Yamada. *Cognition*, *93*, 133-137.

Wang, M., Cheng, C., & Chen, S. W. (2006). Contribution of morphological awareness to Chinese-English biliteracy acquisition. *Journal of Educational Psychology*, *98*(3), 542.

Wimmer, H., & Hummer, P. (1990). How German-speaking first graders read and spell: Doubts on the importance of the logographic stage. *Applied Psycholinguistics*, *11*(04), 349-368.

Wimmer, H., Landerl, K., Linortner, R., & Hummer, P. (1991). The relationship of phonemic awareness to reading acquisition: More consequence than precondition but still important. *Cognition*, *40*(3), 219-249.

Wimmer, H., & Goswami, U. (1994). The influence of orthographic consistency in reading development: word recognition in English and German children. *Cognition*, 51: 91-103.

Yap, M. J., & Balota, D. A. (2009). Visual word recognition of multisyllabic words. *Journal of Memory and Language*, 60, 502–529.

Yoon, H. K., Bolger, D. J., Kwon, O. S., & Perfetti, C. A. (2002). Sublexical processes in learning to read: A difference between Korean and English. *Precursors of functional literacy*, 11, 139-163.

Ziegler, J. C., & Jacobs, A. M. (1995). Phonological information provides early sources of constraint in the processing of letter strings. *Journal of Memory and Language*, 34(5): 567-593.

Ziegler, J. C., & Ferrand, L. (1998). Orthography shapes the perception of speech: The consistency effect in auditory word recognition. *Psychonomic Bulletin & Review*, *5*(4), 683-689.

Ziegler, J. C., Perry, C., & Coltheart, M. (2000). The DRC model of visual word recognition and reading aloud: An extension to German**.** *European Journal of Cognitive Psychology 12* (3), 413-430.

Ziegler, J. C., Jacobs, A. M., & Klueppel, D. (2001). Pseudohomophone effects in lexical decision: Still a challenge for current word recognition models. *Journal of Experimental Psychology: Human Perception and Performance* 27(3): 547-559.

Ziegler, J. C., Perry, C., Jacobs, A. M., & Braun, M. (2001). Identical words are read differently in different languages. Psychological Science, 12, 379–384.

Ziegler, J. C., Perry, C., Ma-Wyatt, A., Ladner, D., & Schulte-Körne, G. (2003). Developmental dyslexia in different languages: Language-specific or universal? *Journal of Experimental Child Psychology*, 86: 169–193.

Ziegler, J. C., Ferrand, L., & Montant, M. (2004). Visual phonology: The effects of orthographic consistency on different auditory word recognition tasks. *Memory & Cognition*, *32*(5), 732-741.

Ziegler, J. C., & Goswami, U. (2005). Reading acquisition, developmental dyslexia, and skilled reading across languages: a psycholinguistic grain size theory. *Psychological bulletin*, *131*(1), 3.

Ziegler, J. C., & Muneaux, M. (2007). Orthographic facilitation and phonological inhibition in spoken word recognition: A developmental study. *Psychonomic Bulletin & Review*, *14*(1), 75-80.

Ziegler, J. C., Petrova, A., & Ferrand, L. (2008). Feedback consistency effects in visual and auditory word recognition: where do we stand after more than a decade? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *34*(3), 643.

Ziegler, J.C., Bertrand, D., Tóth, D. Csépe, V., Reis, A., Faísca, L., Saine, N., Lyytinen, H., Vaessen, A., & Blomert, L. (2010). Orthographic Depth and Its Impact on Universal Predictors of Reading: A Cross-Language Investigation. *Psychological Science*, 21(4) 551-559.

Zwitserlood, P., Bölte, J., & Dohmes, P. (2002). Where and How Morphologically Complex Words Interplay with Naming Pictures. *Brain and Language* 81: 358–367

Zusammenfassung

Kinder, die im Unterricht die Schriftsprache erlernen, gewinnen Einblicke in das System, mit dem geschriebene Wörter Einheiten gesprochener Sprache ausdrücken. Es wird angenommen, dass unerfahrene Leser*innen einzelne Worte überwiegend mithilfe der phonologischen Rekodierung erlesen, d.h., dass sie schrittweise eine lautliche Repräsentation des Geschriebenen herleiten und diese Lautform nutzen, um die Worte zu erkennen. In der Leseforschung besteht die Ansicht, dass während der Identifizierung eines geschriebenen Wortes, auch beim leisen Lesen, automatisch lautsprachliche Informationen zugänglich gemacht werden (z.B. Frost 1998; vgl. aber z.B. Taft & van Graan 1998). Einige Forscher*innen nehmen an, dass die automatische Aktivierung phonologischer Informationen beim Lesen mit zunehmender Leseerfahrung an Bedeutung verliert (z.B. Coltheart et al. 2001), während andere davon ausgehen, dass die automatische phonologische Aktivierung beim geübten Lesen weiterhin eine wichtige Rolle spielt, nur mag sie kaum messbar sein, da es sich um einen hochautomatisierten Prozess handele (z.B. Frost 1998). Ein Grund für die automatische phonologische Aktivierung beim Lesen könnte in der Unterstützung des Arbeitsgedächtnisses liegen (Baddeley et al. 1981). Bislang wurde allerdings nur unzureichend erforscht, welche Einheiten der Lautsprache von der automatischen Aktivierung betroffen sind (z.B. Ashby 2006). Zudem stammt ein Großteil der empirischen Befunde aus Studien zur Wortverarbeitung im Englischen (Share 2008). Die englische Orthographie ist im Vergleich zu anderen alphabetischen Schriftformen besonders intransparent, was sich nachweislich auf die Verarbeitung geschriebener Wörter auswirkt (z.B. Ziegler & Goswami 2005). Daher lassen sich Erkenntnisse zum Englischen nicht ohne weiteres auf andere Sprachen übertragen. Studien, die sich mit anderen Sprachen befassen, sind erforderlich, um bestehende theoretische Modelle der Wortverarbeitung auf eine breitere empirische Basis stellen zu können. Darüber hinaus mangelt es an Untersuchungen zum Lesen mehrsilbiger Wörter, das heißt, bisherige Theorien basieren überwiegend auf Befunden aus der monosyllabischen Wortverarbeitung (siehe Perry et al. 2007).

Die vorliegende Arbeit trägt dazu bei diese Forschungslücke zu schmälern, indem sie sich mit der Interaktion lautsprachlicher und schriftsprachlicher Informationen in der kognitiven Wortverarbeitung des Deutschen beschäftigt. Das Deutsche zählt im Gegensatz zum Englischen zu den eher transparenten Schriftsprachen (z.B. Borgwaldt et al. 2004). Im Rahmen dieses Dissertationsprojekts wurden Studien durchgeführt, welche die Aktivierung

lautlicher Information beim Wortlesen sowie die Aktivierung orthographischer Information in der auditiven Wortverarbeitung des Deutschen untersuchten. Dabei wurden verschiedene Fragestellungen betrachtet. Der Implicit Prosody Hypothesis zufolge (Fodor 1998, 2002) weisen erfahrene Leser*innen einem gelesenen Satz automatisch eine prosodische Kontur zu. Unklar ist jedoch, ob diese prosodische Kontur nur Merkmale auf der Text- und Satzebene betrifft, oder ob sie bis auf die Wortebene spezifiziert wird (Ashby 2006). Der Hauptteil der vorliegende Dissertationsschrift geht dieser Frage nach, und untersucht, inwiefern prosodische Einheiten auf Wortebene (exemplarisch untersucht: Wortbetonung) beim leisen Wortlesen aktiviert werden, und ob es hierbei Unterschiede zwischen erwachsenen, geübten und jüngeren, weniger geübten Leser*innen gibt. Die diskutierten Resultate deuten darauf hin, dass wortprosodische Einheiten in die automatische phonologische Aktivierung involviert sind, was sich in den Reaktionen jüngerer, unerfahrener Leser*innen zeigt (Kapitel 4 und 5). Somit bestätigen die Ergebnisse die Implicit Prosody Hypothesis und stützen die Annahme, dass beim leisen Lesen auch prosodische Merkmale auf Wortebene verarbeitet werden.

Die Beobachtungen der ersten Studie zeigen, dass Grundschulkinder dazu neigen, das Betonungsmuster zuzuweisen, welches am häufigsten in der gesprochenen Sprache auftritt. Erwachsene zeigten dieses Muster nicht. Eine Folgeuntersuchung ging daher der Frage nach, ob es implizite Hinweise auf das Betonungsmuster eines Wortes gibt, das geübte Leser*innen nutzen könnten. In einer Korpusuntersuchung konnte gezeigt werden, dass das häufige Auftreten bestimmter Zeichenfolgen in Wörtern mit einer bestimmten Betonung als ein solcher Hinweis genutzt werden könnte. Die vorliegenden Befunde können dahingehend gedeutet werden, dass mit zunehmender Leseerfahrung vorhandene, orthographische Hinweise automatisch verarbeitet werden, um einem Wort beim Lesen ein Betonungsmuster zuzuweisen. Die Verarbeitung implizit in der Orthographie enkodierter Hinweise auf wortprosodische Eigenschaften hängt folglich mit dem Zuwachs an orthographischem Wissen im Verlauf der Schriftsprachentwicklung zusammen. Es kann angenommen werden, dass der Erwerb solcher impliziten Hinweise einen typischen Schritt in der Schriftsprachentwicklung darstellt.

Wenn phonologische Informationen automatisch beim Wortlesen aktiviert werden, gilt es auch umgekehrt, dass orthographische Informationen aktiviert werden, wenn ein Wort gehört wird? Bisherige Untersuchungen zu dieser Frage geben Anlass zu der Annahme, dass schriftkundige Sprecher*innen automatisch Zugang zu orthographischem Wortwissen erlangen, wenn sie ein Wort hören (z.B. Perre, Bertrand & Ziegler 2011). Einige Forscher sind der Ansicht, dass orthographische Einflüsse auf die auditive Verarbeitung im Verlauf der Schriftsprachentwicklung zusammen mit dem individuellen orthographischen Wissensumfang zunehmen (z.B. Ventura et al. 2004). Die vorliegende Arbeit geht dieser Frage in Bezug auf die Wortverarbeitung im Deutschen nach. Ein weiteres Experiment mit jüngeren, weniger erfahrenen und erwachsenen, erfahrenen Leser*innen verfolgte die Frage, ob sich erworbene Schriftsprachkenntnisse auf die Verarbeitung der gesprochenen Sprache auswirken. Die Ergebnisse zeigen, dass orthographisches Wortwissen bereits früh in die Verarbeitung gesprochener Wörter involviert ist. Da kein Unterschied zwischen den Probandengruppen festgestellt wurde, kann die Hypothese, dass orthographische Effekte im Verlauf der Schriftsprachentwicklung zunehmen, weder abgelehnt noch bestätigt werden. Es wird angenommen, dass Wissen über die Schreibform eines Wortes dabei hilft, eine hochspezifische, abstrakte Repräsentation eines gehörten Wortes aufzubauen, um das Arbeitsgedächtnis zu stützen (Taft 2011). Die Aktivierung orthographischer Information beim Worthören könnte also analog zur Aktivierung phonologischer Information beim Wortlesen in der Unterstützung des Arbeitsgedächtnisses begründet sein. Das frühe Auftreten orthographischer Effekte bei der Bewältigung einer Aufgabe zur auditiven Wortverarbeitung unterstreicht die Bedeutung orthographischer Kenntnisse, welche hinausgeht über die Fähigkeit, eine korrekte Schreibform für ein Wort produzieren zu können (vgl. Klicpera et al. 2010). Kinder, die eine Schriftsprache erlernen, sollten möglichst frühzeitig und umfassend mit orthographisch korrektem Material arbeiten, damit sich orthographisches Wortwissen einprägen kann.

Zusammenfassend konnte gezeigt werden, dass lautsprachliche und schriftsprachliche Informationen in der Wortverarbeitung eng verknüpft sind. Beim leisen Lesen wird eine phonologische Repräsentation des Geschriebenen erstellt, die auch prosodische Merkmale enthält. Vermutlich verarbeiten erfahrene Leser*innen implizite orthographische Hinweise, die die Erstellung eines korrekten Betonungsmusters ermöglichen. Beim Worthören kann auf orthographisches Wortwissen zurückgegriffen werden, das den Aufbau einer abstrakten, visuell angereicherten Repräsentation des Gehörten erleichtern kann. Der Schriftspracherwerb eröffnet demnach nicht nur einen wichtigen Zugang zu höherer Bildung, sondern er verändert auch den Zugang zur Sprache.

Erklärung zu den Gemeinschaftspublikationen

Diese kumulative Dissertation basiert auf drei veröffentlichten Artikeln: Beyermann & Penke (2014a, b) und Beyermann (2013).

Die zwei gemeinschaftlichen Artikel (Beyermann & Penke 2014a, b) sind unter Anleitung und Absprache mit der Zweitautorin Martina Penke eigenständig von mir verfasst worden. Frühere Entwürfe der Manuskripte haben wir dabei gemeinsam diskutiert und in enger Absprache miteinander verändert, wobei ich ausgehend von unseren Absprachen die endgültige Fassung erstellt habe.

Die vorausgehenden Vorbereitungen der Studien, d.h., die Versuchsplanung, die Erstellung des Reizmaterials, die Pilotierung und Durchführung der Experimente sowie die Analyse der erhobenen Daten habe ich nach regelmäßigen gemeinsamen Gesprächen bei Arbeitstreffen in enger Abstimmung mit Frau Penke eigenständig vollzogen. Das heißt, beide Autorinnen waren an jedem Arbeitsschritt maßgeblich beteiligt.

Danksagung

An erster Stelle danke ich Prof. Martina Penke, die mich vor und während der gesamten Promotionsphase mit viel Zeit und Geduld begleitet und unterstützt hat. Mit konstruktiver Kritik, praktischen Vorschlägen sowie mit viel Aufmerksamkeit für das Detail und den roten Faden hat sie mir unzählige hilfreiche Ratschläge gegeben. Vielen lieben Dank für Deine Hilfe Martina! Darüber hinaus möchte ich Prof. Dr. Schabmann herzlich für das zweite Gutachten und für die kritischen Anregungen zu dieser Arbeit danken.

In den schwierigen Zeiten hat mir besonders der Beistand meiner Familie und Freunde sehr geholfen, weiter vorwärts zu streben. Vielen lieben Dank an meine Eltern, meine Schwester Anett und an meine Freunde Susanne, Nadja, Claudia und Friderike, die mich immer wieder aufgemuntert und mir meine Zerstreutheit nachgesehen haben.

Vielen Dank auch an Prof. Guido Nottbusch und Prof. Wolf Schwarz, Prof. Ludo Verhoeven, Dr. Eliane Segers, Dr. Eva Wimmer und Dr. Sarah Verlage sowie Nicole Faulenbach und Felix Golcher für weitere wertvolle Hinweise zu fachlichen Fragen.

Herzlichen Dank an die Lehrkräfte bzw. wissenschaftlichen Mitarbeiter der beteiligten Grundschulen und Universitäten, die mich bei der Datenerhebung unterstützt haben, insbesondere an Uwe Manthey, Antje Jessa, Sandra Rex und Elli Kappler von der Grundschule am Koppenplatz, sowie an Ruben van de Vijver, Solveig Leist und Anthony Eden für die Vermittlung wichtiger Kontakte. Mein Dank gilt auch der Grundschule Klosterfelde, der Grundschule am Koppenplatz und der Universität Potsdam sowie den beteiligten Mitarbeitern für die Hilfe bei der Datenerhebung.

Zudem danke ich der FWO (Fonds Wetenschappelijk Onderzoek, Vlaanderen), die diese Arbeit mit dem Stipendium G.0292.09N, verliehen an Prof. Dr. Martina Penke, finanziell unterstützt hat.