Chapter 7
General discussion
7.1 Introduction

In this thesis it was attempted to unravel some of the complexities surrounding
the definition of reading disabilities (RD), the issue of comorbidity, and
reading-related cognitive component modeling. The main theoretical motive for
the present research project was a rather diffuse theoretical-empirical insight
into the neurocognitive mechanisms that underpin RD, especially when
considering the complexities that come with comorbidity. Therefore, going
beyond the reading-descriptive level, this project has pursued the possibility of
identifying differential neurocognitive profiles for the involved reader groups,
which may advance the development of more concise intervention programs.
Specifically, this project involves the clarification and measurement of well-
known neurocognitive correlates of reading (dis)abilities, i.e., Rapid
Automated Naming (RAN) and Phonemic Awareness (PA), as well as the
investigation of relatively new ones, i.e., those tapping different aspects of
visual attention.

This discussion will be structured as follows. In Section 7.2 some
generalized conclusions are drawn as to: (i) the empirical estimation of the
working model of Chapter 1, (ii) modification of the general working model by
taking into account reading (dis)ability levels and severity considerations, and
(iii) the issue of comorbidity. In Section 7.3 limitations of the present research
are mentioned along with recommendations for future research. Finally,
Section 7.4 provides some closing remarks as to treatment perspectives and the
differential-diagnostic value of the presently employed predictor set.

7.2 Conclusions and implications

Working model

From the results of Chapters 2 through 6 it can be concluded that each one of
the currently involved phonological and visual attention measures significantly
adds to the prediction of reading and RD. Linking the data of these chapters to
the working model of word reading (WR) that was introduced in Chapter 1, the
general picture is as follows. With the presently involved measures, i.e.,
alphanumeric RAN (RANₐn), phonemic awareness (PA), selective visual
attention (attentional blink; AB), and orienting of attention (visuo-spatial
cueing task; VCT), as predictors of WR fluency, the total proportion of explained
WR variance amounts to 84 percent. Figure 7.1 illustrates that on the basis of
phonological processing alone, as operationalized by RAN<sub>an</sub> and PA, an estimated 71 percent of total WR variance can be explained, with RAN<sub>an</sub> being indicated as the clear winner in terms of uniquely explained WR variance. Consistent with the recent literature (Landerl et al., 2013), this finding strongly emphasizes the theoretical relevance of both types of phonological processing and shows that these tasks constitute a very effective set of predictors for differential-diagnostic assessment procedures. However, if controlled for visual attention, the unique contribution of phonological processing to WR is dramatically reduced to 30 percent. Therefore, it is clear that when it comes to the relationship with WR fluency, visual attention and phonological processing involve a quite substantial shared variance component as well.

Moreover, as indicated in Figure 7.1, visual attention contributes significantly to the WR prediction by explaining a significant amount of unique variance on top of phonological processing, with orienting of attention showing as the strongest unique predictor. More specifically, as demonstrated in Chapter 6, orienting of attention was found to be substantially linked to RAN tasks and WR, which suggests that children with RD experience significantly more problems than normal reading children with shifting focal attention to a different spatial location. This orienting deficit seems to inhibit the normal stimulus identification process, with further cascading negative effects for higher-order processing. In addition, Chapter 5 demonstrated that the AB also adds significantly to the prediction of WR. However, this task was found to be substantially linked cross-modally with the PA tasks, which may possibly be due to a common link to working memory and executive functioning. The literature suggests that PA tasks such as those currently employed involve a more
substantial memory load than RAN tasks (Landerl & Wimmer, 2000). Similarly, AB tasks are presumably also tapping working memory because of the dual processing task requirements (Dux & Marois, 2009). Therefore, working memory can be considered as a relevant mediator between WR and PA and AB tasks, which should be controlled for. The reader is referred to Chapters 5 and 6 for more detailed information on the regression analyses for the individual attention tasks. Thus, it can be concluded that visual attention explains a substantial extra proportion of variance in the prediction of WR fluency, and these tasks evidently are suitable control variables for the measurement of higher-order phonological processing. Despite the fact that in the present research different visual attention tasks were used than in other recent studies, e.g., the visual attention span (Bosse et al., 2007; Lallier, Donnadieu, & Valdois, 2013; Van den Boer, De Jong, & Haentjens-van Meeteren, 2012), the conclusions are similar: Visual attention is evidently relevant to the process of reading that constitutes a promising novel branch of research into reading (dis)ability.

Reading (dis)ability levels

An important theoretical implication of the results of Chapter 2 is that the predictive patterns of reading-related cognitive processes are likely to be modified by the severity of RD. Thus, when it comes to phonological processing, this study indicates that it is important to consider WR ability level. The relationships of RAN, and PA in particular, with reading ability were found to be strongest for the poorest readers. This has clear implications for the correct interpretation of the Double Deficit Hypothesis (DDH) (Torppa et al., 2012; Wolf & Bowers, 1999). The DDH framework gains validity with the severity of the reading impairment. Moreover, the finding of relatively greater PA weaknesses in the poorest reader groups (De Groot et al., 2015), as compared to RAN, can possibly aid treatment planning. More specifically, with the severity of RD, scaffolding phonemic skills should receive relatively stronger emphasis in interventions (Gough, 1996). A final comment on the notion of differential relationships for WR ability levels is that the presently provided general estimates of the above working model are dependent of the sample being investigated. As compared to the estimates found in the presently studied clinical samples, and consistent with the results of other studies of the general population (Landerl et al., 2013; Van den Bos, 2008), the effects of reading-related processes effects were much smaller in normal readers.

Comorbidity

While acknowledging that the assignment to the (comorbid) SLI and ADHD groups was necessarily constrained to the application of a singular arbitrary WR criterion (see also study limitations in the next section), the present study
has yielded some notable similarities and differences between the RD subgroups. For instance, the finding of largely additive effects in the comorbid groups suggests that the reading component of these disorders is not qualitatively different for the RD-only and comorbid groups. In relation to ADHD, this is clearly reflected by the finding of equally poor WR performances, the fact that comorbid ADHD does not seem to enlarge phonological impairments, and that the RD-only and RD+ADHD groups do not show markedly different underlying profiles of PA and RAN. Together, these findings suggest that RD and ADHD operate on RAN and PA rather independently, with only a small (added) effect of ADHD. Therefore, a sharp diagnostic differentiation between RD-only and comorbid RD+ADHD seems unwarranted on the basis of phonological processing alone.

As to SLI, things are somewhat different, as RD and SLI appear less clearly dissociated. In this case, WR performance was found to be (slightly) more severely impaired in the comorbid group relative to the RD-only group. Moreover, the present results indicate that comorbidity of SLI does substantially exacerbate problems with phonological processing in children with RD, PA in particular. However, as with RD and ADHD before, the absence of substantial interactions between RD and SLI is also suggestive of largely additive effects as to phonological processing. As compared to ADHD, the SLI-related contribution to phonological processing deficits is, however, much larger. Combined with the finding of larger effects in the SLI-only group, these results are consistent with the general notion of phonological processing deficiencies being a characteristic of SLI as well as RD (e.g., Vandewalle et al., 2012). As such, RD and SLI can be considered as similar but distinct phonologically linked disorders, which are primarily differentiated by additional oral language deficits that operate independently on phonological processing in children with SLI (cf. Bishop & Snowling, 2004).

Although generally more pronounced in the presently investigated children with SLI, a shared attribute of children with RD+ADHD and RD+SLI, as compared to those with RD-only, is that these groups seem more prone to difficulties with tasks involving a relatively high working memory load. The results for the presently employed PA_{substitution} task (Chapters 3 and 4), and the Attentional Blink task (Chapter 5) provide examples. However, in order to correctly interpret the comorbid groups’ poor PA performance, and to differentiate the assumed mainly phonological-linguistic component, it would be mandatory to more explicitly consider working memory capacity and executive functioning capabilities in conjunction with PA task performances.

Based on the present results, RAN_{an} performance and orienting of attention can be considered as best candidates of the currently involved reading-related processes to differentiate between RD, and ADHD or SLI. In both studies that investigated phonological processing in these groups of children, i.e., Chapters
3 and 4, RAN\textsubscript{an} was found to be more strongly associated to RD than to ADHD or SLI, respectively, as reflected by much larger effect sizes for RAN\textsubscript{an} in the RD groups. Similarly, a RD specific effect was found for response times on the visuo-spatial cueing task (VCT), which differentiated between children with RD and normal readers. The neurophysiological VCT measurements indicated further differentiating effects of dysfunctional orienting of attention (Chapter 6). That is, as compared to controls, children with RD were found to be more severely impaired on attention shifting capabilities than the comorbid groups. Additionally, some qualitative differences were found between the ERPs of the RD-only and comorbid group (i.e., amplitude vs. latency). These results were interpreted as part of an explanation for the well-established RAN-reading link, which seems to be particularly pronounced in children with RD-only. Although still substantial, orienting of attention seemed to play a smaller role in the reading problems of comorbid children.

To conclude, a practical concern of the present study has been the formalization of the diagnosis and treatment of dyslexia in the Netherlands according to the Protocol Dyslexia Diagnosis and Treatment (PDDT) (Dutch Health Care Insurance Board; Blomert, 2006). In its current form the PDDT favors cases of relatively ‘pure’ RD as eligible for insured further diagnostic assessment, and specialized reading treatment. As a consequence, comorbid cases of RD+ADHD or RD+SLI are both at risk of being excluded from these assignments. In this context, the present study carries relevant practical implications for the differential diagnosis and treatment of groups with RD and ADHD or SLI, and offers a new perspective on this possibly too restrictive usage of the PDDT. That is, results have been presented that emphasize the importance “distinguish” for comorbidity, and that such distinctions might form a basis for differential treatment planning. However, based on the present findings, a sharp aggregated differential-diagnostic differentiation between children with RD-only and children with different comorbid problems seems unwarranted.

7.3 Limitations and future directions

This section discusses the following limitations of this thesis with some suggestions for future studies: sample sizes, group assignments, the recruitment from clinical samples, the factor of age, and characteristics of the visual attention tasks.

First, the relatively small sample sizes of the presently studied comorbid groups posed a clear limitation to the investigations of the RD+SLI and RD+ADHD groups. Especially with regard to the electrophysiological measurements of Chapter 6, relevant effects may have been missed due to lack
of statistical power, whereas the interpretations of the statistically significant results for these groups cannot be generalized. In some instances the comorbid groups were integrated to increase power (e.g., Chapter 6). However, although not for the variable of interest, i.e., orienting of attention, it is obvious these groups are likely to be heterogeneous for other characteristics which might influence reading-related processes. Therefore, considering the present results, a further investigation of these relationships with larger SLI and ADHD groups seems warranted.

Secondly, it should be noted that the previously discussed WR-criterion dependency of cognitive reading-related processes obviously extents to the presently discerned SLI and ADHD groups, and that, for practical reasons, assignment to these groups was based on a singular WR cutoff criterion. Thus, as the cognitive reading-related effects reported for the SLI-only and ADHD-only, and comorbid groups are confined to this single WR criterion, it is possible that a different RD criterion would have yielded different results. This makes any (sub)group division a precarious and limiting undertaking, and it may be worthwhile for future study to validate the outcomes for different WR classification criteria.

Furthermore, as the children with ADHD and SLI that have participated in the present study were drawn from clinical samples, it should be noted that the resulting subgroups may not be representative of the larger population of attentional or language impaired children. There is literature which suggests that the use of clinical samples likely inflates comorbidity rates (Catts et al., 2005). This means that if recruiting from clinical samples, one is likely to receive the most severe cases, and these cases probably also qualify for multiple disorders. For a discussion of this issue in relation to, e.g., the overlap of RD and SLI see Catts et al. (2005), which included participants drawn from an epidemiological sample (also see Baird et al. (2011) for a brief related discussion). However, this is why a convenience sample was used in the first place, as the primary interest of this study was in children with comorbid disorders, while at the same time distinguishing SLI-only and ADHD-only groups for validation purposes. It should, therefore be emphasized that the present study is not meant as an epidemiological study providing accurate estimates of comorbidity rate, as the reported overlap rates of this study might be inflated. Is it possible, however, that the presently uncovered additivity levels may be less pronounced in population-based samples.

In Chapter 2 age was regarded across-the-board, while differentiating for WR ability levels. Although the effect patterns seem robust for age, which allows for the interpretation of children with RD having enduring problems with sub-lexical processing, such a conclusion necessarily remains tentative, as verification requires a comprehensive developmental design which discerns WR ability levels as well. Therefore, it would be very insightful to validate the
present effect patterns for phonological processing using a cross-sectional
design, with a sample size that allows for WR skill differentiations within each
age level. Moreover, it seems reasonable to assume that the ‘severity-
dependence’ claim might similarly apply to the (cascading) reading-related
effects of visual attention. A separate investigation of the presently involved RD
subgroups indeed revealed larger reading-related effects of both visual
attention tasks, relative to those found for the general population-based
sample. These findings give further support to the nowadays widely held idea
that reading (dis)ability is multifactorial in nature (Pennington et al., 2012).
Additionally, these findings show that it is important to distinguish for different
ability levels when studying the effects of reading-related cognitive processes:
in other words severity matters.

In relation to the Attentional Blink task (Chapter 5), a substantial co-varying
effect of age was found, which indicates that the presently employed AB task
was significantly more difficult for younger children. Thus, there is a clear
developmental aspect to this task. However, it is not clear whether the effect of
age should be attributed to selective attention, or to the highly intertwined
processes involved with working memory, which are also known to mature
with age (e.g., Thomason et al., 2009). Therefore, it is recommended to include
separate working memory tasks in future studies, and to develop and employ
age-appropriate versions of the task, employing optimized RSVP interstimulus
and presentation duration parameters. Furthermore, there is reason to include
longer SOA conditions in the task, as the AB curves for the investigated groups
were not asymptotic for a stimulus onset asynchrony of 770 milliseconds (i.e.,
the Lag-7 condition). There is evidence for the assumption that children with
RD require larger interstimulus intervals, i.e., longer SOAs, to fully recover from
an AB. In other word, these children may show a prolonged attentional dwell
time (Hari et al., 1999). However, in the present study such conditions were
deliberately omitted, because more conditions equal more trials and prolonged
testing sessions. In the present thesis this was considered undesirable in terms
of the total experiment planning. A more general point is that the AB, in
contrast to adults, has been relatively under-investigated in children, especially
in relation to reading (dis)abilities. The present findings clearly warrant further
psychometric and validation study of the attentional blink in this applied
context.

Finally, with regard to orienting of attention, Chapter 6 mentioned that
there is a temporal aspect to the primarily visuo-spatial cueing task (VCT) as
well. Although a direct comparison of the presently employed VCT and the
dual-target attentional blink task of Chapter 5 seems problematic (because of
different task characteristics), it is likely that RD groups, particularly children,
are impaired on serial information processing in addition to problems with
orienting of attention. This would explain why the presently studied groups of
children with RD seem most severely impaired on the ability to shift attention from cues to opposite peripheral targets in the VCT, which are only 150 milliseconds apart. Therefore, children with RD appear to run into double trouble if they are pushed beyond their processing speed capabilities (cf. Facoetti et al., 2000). As indicated in Chapter 6, it would be very interesting to compare the aforementioned paradigms directly and in conjunction with recently rather frequently applied visual attention span tasks (Bosse et al., 2007; Lobier et al., 2012). This would enable a further disentanglement of visuo-spatial and temporal aspects of these tasks. Moreover, in line with McGrath et al. (2011), general processing speed appears to be a common attribute of all tasks involved, which might differentiate children with RD from normal readers. For example, longer VCT response times evidently are a specific characteristic of all RD groups, i.e., RD-only, RD+ADHD and RD+SLI. Importantly, the presently employed RAN and PA tasks involve a large speed component as well. Thus, to further clarify the unique WR contributions of the presently involved cognitive reading-related processes, it is recommended for future study to include a direct measurement of general processing speed.

7.4 Final remarks

This last section will first address some practical considerations for future study as to the applied question whether it is possible to conceive differential intervention strategies for the presently involved groups. That is, can the present insights modify treatment planning to facilitate tailor-made care?

Based on the present finding of relatively greater PA weaknesses in the poorest reader groups (Chapter 2), a first tentative answer to the above question is that it may be worthwhile to conduct effect studies aiming to develop and evaluate WR ability-based treatments which incorporate a systemic implementation of intensified phonemic skill building with the level of RD to foster WR fluency in the poorest reader groups (Gough, 1996). A similar approach could be taken with RD groups with SLI or ADHD, where relatively strong emphasis should be placed on phonemic skills (with SLI) and working memory abilities.

In connection with the finding of a specific orienting of attention deficit in children with RD (chapter 6), a second answer is that the combination of self-paced reading paradigms (Chiarenza, Olgiati, Trevisan, Marchi, & Casarotto, 2013; Ditman, 2007; Reed, 2013; Tressoldi, Vio, & Iozzino, 2007; van der Schoot, Vashinder, Horsley, Reijntjes, & van Lieshout, 2009) and eye tracking gaze contingency technology presents a promising future direction for RD research. As yet, the self-paced reading paradigm has been most frequently applied in the context of reading comprehension. However, based on the
present findings, it seems that – especially when combined with eye tracking technology – the ‘moving window paradigm’ provides an adequate online method to help children with specific RD to remain focused while decoding a word or word fragment, by suppressing (irrelevant) peripheral visual information. Considering the inhibitory aspect of this paradigm, also children with concomitant ADHD possibly may benefit from this approach, as these children are known to experience inhibitory problems (e.g., Johnstone, Barry, & Clarke, 2007).

Finally, returning to the main issue of neurocognitive profiles, the present study emphasizes the importance of all presently involved reading-related processes. Alphanumeric RAN, and particularly PA, were found to be highly predictive for RD, whereas efficient RAN performance seems to characterize excellent readers. Moreover, the combination of RAN and PA was found to be most effective predictor overall, with the largest effects found in the comorbid groups. As compared to phonological processing, both the orienting of attention and attentional blink paradigm – as yet – have received relatively little attention by researchers. However, the results of the present study add to the conclusion that these non-phonological processes are relevant to reading (Pennington et al., 2012), and certainly warrant further investigations of either aspect of visual attention. It has been demonstrated that spatial and temporal aspects of visual attention add significantly to the clarification of differentiated cognitive profiles for the presently involved subgroups, and offer a great deal of refinement to ‘traditional’ diagnostic procedures. Concordantly, it seems opportune to finish this thesis with the following preliminary insight.

As there were complete data matrices for small numbers of participants from each of the six subgroups, encompassing all presently involved (neuro)cognitive measurements (i.e., WR, RAN, PA, VCT (including ERP data), and AB), this allowed for a preliminary discriminant function analysis of these data. Figure 7.2 shows the six subgroups plotted against the first two out of four significant (Wilks’ λ’s < .001, p < .001) separating canonical discriminant functions, with the group centroids indicated by the blue squares.

Remarkably, this preliminary analysis yielded a perfect score of 100 percent of the original grouped cases correctly classified. Although strictly tentative, this tantalizing result most certainly warrants replication with larger numbers of participants, and emphasizes the potential of this set of predictors as elements of a comprehensive cognitive model of reading (dis)abilities. It appears that, despite significant overlap among this set of predictors, each element holds a unique piece of the puzzle, which put together yield an accurate solution to the problem of profiling these groups in terms of neurocognitive processes indeed.
Figure 7.2  Canonical discriminant function plot for six subgroups