■

Anchoring the Deficit of the Anchor Deficit: Dyslexia or Attention?

Edith Willburger[1] and Karin Landerl[2,*]

[1]*University of Salzburg, Salzburg, Austria*
[2]*University of Tuebingen, Tuebingen, Germany*

In the anchoring deficit hypothesis of dyslexia (*Trends Cogn. Sci.*, 2007; **11**: 458–465), it is proposed that perceptual problems arise from the lack of forming a perceptual anchor for repeatedly presented stimuli. A study designed to explicitly test the specificity of the anchoring deficit for dyslexia is presented. Four groups, representing all combinations of reading skills (high or low) and attention (high or low), were given a time estimation task in which a standard tone was compared with tones of varying length. Poor readers showed problems only if they had limited attentional skills as well, while poor readers with good attention were unaffected. It is concluded that a single deficit in time estimation is not sufficient to cause reading deficits. Copyright © 2010 John Wiley & Sons, Ltd.

ANCHORING THE DEFICIT OF THE ANCHOR DEFICIT: ATTENTION RATHER THAN DYSLEXIA

Dyslexic individuals have repeatedly been demonstrated to be impaired on a variety of sensory tasks. A controversially debated question is whether perceptual deficits are causally related to reading disorders or rather an associated marker for deviant brain development without direct impact. Ahissar and colleagues recently identified a common protocol among the various different tasks that have been used to assess sensory impairments. Typically, a (small set of) standard stimulus(/-i) has(/-ve) to be checked against

*Correspondence to: Karin Landerl, Department of Psychology, University of Tuebingen, Christophstr. 2, 72072 Tuebingen, Germany. E-mail: Karin.Landerl@uni-tuebingen.de

varying comparison stimuli. Generally, participants show improved performance after repeated exposure to a reference tone as comparison with an internal reference substitutes comparison with the real reference tone. According to Ahissar (2007), dyslexic individuals fail to form such a perceptual anchor (Harris, 1948) and do not profit from a repeated reference stimulus. Ahissar explained this anchoring deficit in terms of deficient bottom–up attentional mechanisms, while top–down attentional processes are unaffected. Such a deficit would explain dyslexics' poor performance on tasks with very different perceptual demands.

Two types of evidence would seriously challenge this interesting new conception. First, dyslexic performance should only be deficient under conditions where controls are able to form a perceptual anchor. In contrast to this prediction, Ziegler (2008) recently showed that dyslexic children's performance in a rapid automatized naming (RAN) and a speech perception task was deficient right from the start, but Ahissar and Oganian (2008) explained this finding by assuming that controls may have built their anchor during practice trials.

Secondly, such a specific attentional deficit may well exist, but it may not be directly related to dyslexia. In her recent study, Ahissar (2007) acknowledged that the prevalence of combined attention and reading disorders is high, but argued that many individuals with an attention disorder have no reading difficulties. The implications of this argument are that (i) general attention deficits do not necessarily cause dyslexia and (ii) any attentional deficit that is related to dyslexia must be specific. However, the specificity of the anchor deficit for dyslexia has so far not been explicitly tested. More precisely, the prediction is that an anchoring deficit should be apparent in dyslexic children (irrespective of comorbid attentional problems) but not in children with attentional deficits and adequate reading skills.

A paradigm for which the anchor hypothesis provides an interesting alternative explanation is a time estimation (TE) task (Nicolson, Fawcett, & Dean, 1995), requiring participants to decide which of two tones is longer. The first tone is always of standard length while the duration of the second tone varies. Nicolson *et al.* explained dyslexic children's poor performance on this task in terms of a dysfunction of the cerebellum which is involved in temporal processing. However, deficient performance could also arise from failure to build an internal reference. We have recently used this paradigm in a large scale study assessing children's reading and attentional skills. As in most other studies on dyslexia, a clinical diagnosis of ADHD was an exclusion criterion. The general assumption of studies that apply this exclusion criterion is that the attentional skills of participants are mostly within the normal range. However, it is of course possible that some children in the sample would fulfil the diagnostic criteria for ADHD, but have not (yet) received a clinical diagnosis. Furthermore, children with reading deficits may experience minor attentional difficulties. Indeed, there was considerable variability in our sample, enabling us to specifically select subgroups of children with poor reading but good attentional skills and children with adequate reading but relatively poor attentional skills as well as a group with poor reading and attentional skills. Comparing the performance of these groups on TE enabled us to test the predictions of the anchor hypothesis.

METHOD

Participants

Children attending grades 2–4 in local elementary schools took part. Low IQ (<85), German as a second language as well as a clinical diagnosis of AD(H)D were exclusion criteria. Poor readers had to be at least 1.25 SDs below the age norm on a combined score of two reading tests (see below), good readers had z-score $\geqslant -0.5$. Attention impaired children performed more than 1.5 SDs below age norm on two of three subtests of a standardized attention test battery (description below). Children with good attentional skills had z-score $\geqslant -0.5$ on all the three attention subtests. By combining these selection criteria, the four groups presented in Table 1 were formed. To avoid systematic differences in IQ, children with untypically high standard scores of 15 or higher were not admitted to the control group of R+/A+.

Materials

Reading

In a standardized test of reading fluency (Mayringer & Wimmer, 2003) given in class, children had to silently read simple sentences and indicate if the content of the sentence was right or wrong. Test criterion was the number of sentences read within 3 min. For an individually administered One-Minute-Reading Test (Willburger & Landerl, 2009), children had to read a word list with slightly increasing difficulty aloud. The number of words read correctly within 1 min was scored. The correlation between the two reading measures was 0.85, $p < 0.001$.

Table 1. Means (standard deviations) for age, reading, attention, IQ, time estimation, rapid naming, and phoneme deletion

	R+/A+ N = 30	R+/A− N = 20	R−/A+ N = 19	R−/A− N = 19	F(3, 87)	η^2
Age months	110.92 (10.50)	113.23 (11.20)	111.59 (8.38)	116.75 (10.36)	1.38	0.05
Reading[1]	0.44 (0.57)[a]	0.25 (0.53)[a]	−1.59 (0.28)[b]	−1.67 (0.32)[b]	133.30*	0.83
Attention						
Alertness[1]	0.58 (0.30)[a]	−0.83 (1.16)[b]	0.39 (0.34)[a]	−1.40 (1.53)[b]	23.25*	0.45
Flexibility[1]	0.49 (0.46)[a]	−0.90 (1.40)[b]	0.35 (0.49)[a]	−1.15 (2.04)[b]	10.70*	0.28
Sustained attention[1]	0.53 (0.45)[a]	−1.63 (1.68)[b]	0.38 (0.53)[a]	−1.15 (1.10)[b]	25.50*	0.48
IQ						
Similarities[2]	10.93 (1.93)	11.70 (2.68)	10.95 (2.17)	11.21 (3.26)	0.45	0.02
Block design[2]	10.63 (2.33)	9.05 (3.17)	10.79 (3.34)	9.79 (2.92)	1.65	0.06
Time						
Estimation[1]	−0.06 (1.21)[a]	−0.33 (1.00)[ab]	−0.28 (1.24)[a]	−1.46 (1.63)[b]	5.09*	0.15
Rapid naming[1]	0.19 (1.07)[a]	−0.24 (1.02)[a]	−0.91 (0.60)[b]	−1.26 (0.70)[b]	12.55*	0.31
Phoneme						
Deletion[1]	0.26 (0.78)[a]	−0.02 (0.76)[a]	−1.09 (1.10)[b]	−1.23 (1.38)[b]	12.34*	0.31

Pairs with different letters differ significantly.
[1]z-Scores.
[2]Standard scores.
*$p < 0.01$.

Attention

Three subtests of a standardized computer-test battery assessing different aspects of attention (Zimmermann, Gondan, & Fimm, 2002) were carried out. In the subtest Alertness, children had to push a button as quickly as possible whenever a witch appeared in a window in the centre of the screen. Medians and standard deviations of children's response times (RTs) were measured. In the subtest Flexibility, two dragons (green and blue) appeared simultaneously on the left and the right side of a door in the middle of the screen. The dragons changed position inordinately. Children's task was to alternately identify the position of the green and the blue dragon by pressing the left or the right key. Acoustic feedback for errors was given. Medians and standard deviations of RTs and number of errors were measured. The subtest Sustained Attention required responses to subsequent stimuli (ghosts) whenever they had the same colour. The adminis-tration of the altogether 300 trials (including 50 targets) lasted about 10 min. Median RTs as well as errors of commission and omission were recorded.

IQ

One verbal (Similarities) and one nonverbal subtests (Block Design) of the German version of the WISC III (Tewes, Rossmann, & Schallberger, 2000) were administered.

TE

Children had to select the longer of two tones presented via headphones. A standard stimulus (1200 ms) was presented first followed by a shorter or longer comparison stimulus after 500 ms. Stimulus duration ranged from 400 to 2000 ms in steps of 50 ms. Children had to press the left or right mouse key to indicate which stimulus was longer. The weighted up–down method by Kaernbach (1991) was used and the experiment was terminated after 10 reversals, using the arithmetic mean of the last eight reversals as individual threshold. Feedback was only given for six practice items.

RAN

A standard Rapid Digit Naming paradigm (Denckla & Rudel, 1976) randomly repeating four different digits 10 times over five lines was administered. Children were instructed to name the digits as quickly as possible. A practice sheet with 16 items preceded the task.

Phoneme Deletion

A Dutch computerized phoneme deletion (PD) test (Blomert & Vaessen, 2009) was adapted for German. Twenty-seven nonwords of one- to three-syllable length were presented via headphones and the child had to repeat the nonword without a specified phoneme ('/gulst/ without /l/'). Percentage of correct answers was recorded. Corrective feedback was only given for five practice items.

RESULTS

The upper section of Table 1 shows the effect of the selection and matching criteria on descriptive characteristics of the four groups. For each measure, a one-way ANOVA comparing the four groups was calculated. Significant effects were followed up by *post-hoc* Scheffe tests. The two reading impaired groups (R−) had significantly lower reading scores than the two groups of good readers (R+), with no differences between low and high attention groups (R+/A+ vs R+/A− and R−/A+ vs R−/A−). In line with our selection criteria, the pattern was reversed for the three subtests of attention: here, the two groups with low attention had significantly lower scores than the groups with high attention with no differences between good and poor readers. No significant differences were evident for age and IQ.

The lower section of Table 1 presents the results of the TE paradigm. Thresholds were standardized for each grade level on the basis of 181 typically developing children (Grade 2: $M = 270.39$, SD = 131.67, Grade 3: $M = 259.61$, SD = 156.47, Grade 4: $M = 198.52$, SD = 77.76). Although performance of the four groups differed significantly, the differences were only partly in the predicted direction. Only the average threshold of the R−/A− group was reliably higher than that of the control group (R+/A+). The average threshold of the R−/A− group was also significantly higher than that of the R−/A+ group and the difference to the R+/A− group approached significance ($p = 0.062$). The average performance of the R+/A− and R−/A+ groups was similar to each other and not different from the control group. Thus, while an anchor deficit may contribute to poor reading in the R−/A− group, it cannot explain the reading deficits in the R−/A+ group.

To get a more detailed insight into the association of TE and reading, Figure 1 plots individual performance on the TE task against reading performance. It is evident that all the four groups include children who show high performance in the TE paradigm and are obviously well able to form a perceptual anchor. Note, for example, that the poorest reader of the whole sample has a TE *z*-score close to zero. On the contrary, five children with good attention and reading skills performed more than 2 SDs below the reference group. Obviously, there is a large overlap between the groups. Figure 1 shows that only three poor readers are extreme outliers with performance more than 3.5 SDs below the mean of the reference group. Quite strikingly, the two R−/A− children showed an especially marked impairment of sustained attention (*z*-score ⩽ −2.2) and all three children were deficient in PD (*z*-score ⩽ −0.84) and RAN (*z*-score ⩽ −1.31).

The lower section of Table 1 presents *z*-scores (based on the reference sample of 181 typically developing children) for RAN and PD separately for the four groups. In both the tasks the two R+ groups performed at a significantly higher level than the two R− groups with no effect of attention.

Finally, we inspected correlations (Spearman) of TE, RAN, and PD with reading. All three coefficients were significant ($p ⩽ 0.004$), but lower for TE (0.31) than for RAN (0.52) and PD (0.57). Performance in the TE paradigm was substantially related to attention (0.39, $p < 0.001$) with comparable correlation coefficients for the three different attentional measures that were combined in this score (alertness: 0.26, flexibility: 0.32, sustained attention: 0.34).
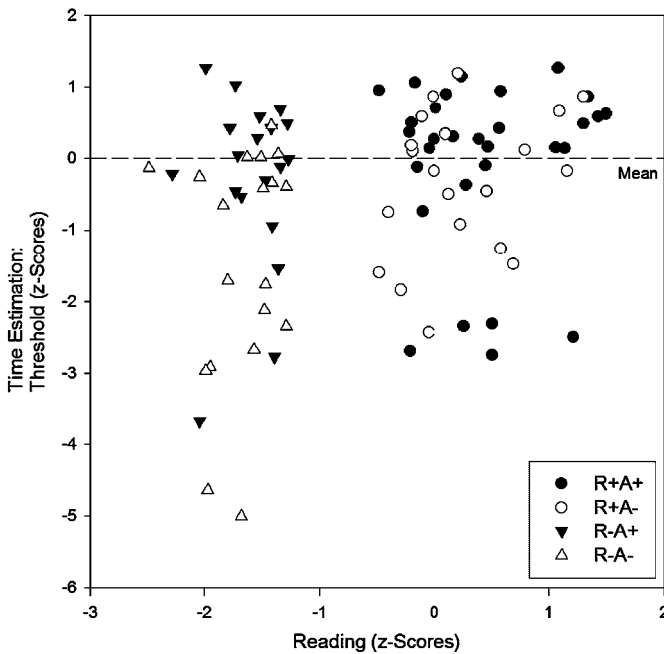
Figure 1. Scatterplot of individual reading and TE z-scores separately for the four ability groups.

DISCUSSION

In the current study, a TE paradigm was employed to test the perceptual anchoring hypothesis of dyslexia. We observed largely overlapping TE performance in four groups of children with good and poor reading skills and good and poor attentional skills, making it unlikely that a deficit to form a perceptual anchor is a central cause of dyslexia. More specifically, deficient TE performance was found to co-occur with good reading in a substantial number of participants. Also, in contrast to the predictions of the anchor deficit hypothesis was the finding that poor readers with adequate attentional skills did not experience any particular problems in the TE paradigm. Only children with a combination of poor reading and poor attentional skills showed reliably prolonged thresholds. Performance on the TE task showed a significant but only moderate association with reading. The most adequate explanation for this pattern of findings is that poor TE performance is not sufficient to cause reading problems, but when TE deficits occur in association with more general attentional problems, they may well contribute to the manifestation of the reading deficit.

Note that our finding of a systematic association of TE performance with poor reading in our R−/A− group can also not unequivocally be interpreted as evidence in favour of the anchor deficit view. To draw this conclusion, it would be necessary to contrast performance in a TE paradigm that allows forming a perceptual anchor with a control paradigm that assesses TE without the option to form such an anchor. Such a contrast was reported by Ahissar (2007) for auditory as well as visual perception. Unfortunately, we were not able to include such a

no-reference control task in our study, so that it remains unclear whether children in the R−/A− group experienced specific problems in anchor formation or more general deficits in auditory or temporal processing.

A serious limitation of our findings would be whether the tasks administered to assess attentional skills in one way or another depended on setting a (perceptual) anchor as this would imply that the selection criterion might be confounded with an anchoring deficit. However, none of these tasks repeated standard stimuli over trials or required storing information in working memory. In contrast, all the three tasks required continuous updating of the information in working memory store. For example, in the sustained attention test children had to respond when two ghosts of the same colour appeared in immediate succession. Inadequately, building a perceptual anchor would rather induce errors instead of facilitation effects. Thus, poor performance on this task results from what Ahissar (2007) called top–down driven attentional skills and may even indicate over-reliance on, but certainly no particular deficit in bottom–up driven attentional skills. Still, the two children with the highest thresholds in the TE task showed particularly poor sustained attention. Note that these two children also had deficient phonological skills. Thus, they would negatively influence any mean score comparison (anchoring, phonological skills, attentional skills) with a group of typically developing children, but causal attributions are extremely difficult.

While our data do not confirm the anchoring deficit hypothesis of dyslexia, they are largely in line with the standard phonological deficit account. Children with reading deficits performed poorly on RAN and PD, irrespective of attentional deficits and children with low attention but intact reading skills did not show a phonological deficit. Ahissar and Oganian (2008) have pointed out that poor RAN performance may be an indication of an anchoring deficit as presentation and repetition of the relevant stimuli during practice trials already allows formation of an anchor for these stimuli. Analogously, Ahissar explained poor performance in phonological awareness tasks in terms of an anchoring deficit as they would typically 'require efficient retention and access to recently presented stimuli' (Ahissar, 2007, p. 463). We find this explanation is not very convincing, as standard phoneme manipulation tasks like the deletion paradigm do not involve any repetition of small sets of stimuli. Still, in the current study, this explanation fits with the empirical findings for the R−/A− group; however, a general anchoring deficit cannot explain poor phonological skills in the R−/A+ group as all but four of these children showed adequate performance in TE (z-scores higher than −1).

Our pattern of findings is similar to a recent study by Ramus, Pidgeon, and Frith (2003) who also observed poor phonological awareness in dyslexic children, but no significant difference compared with a control group in TE, although dyslexics' average threshold tended to be prolonged. Note that in this study, almost half of the dyslexic participants also had a clinical diagnosis of ADHD. It is likely that only the comorbid children had problems to perform the task, while children with isolated reading disorder may have performed on the same level as the controls, resulting in a somewhat distorted mean score.

Obviously, our findings are also contradictory to the cerebellar deficit account (Nicolson *et al.*, 1995), assuming that the TE paradigm might indicate cerebellar dysfunction in dyslexic individuals. The current study illustrates that controlling attentional skills is extremely important in research on learning disorders. We

could show that excluding children with ADHD from dyslexia samples is not sufficient as even then dyslexic children will often have lower attentional skills than controls. In many studies employing psycho-physiological measures, this fact is ignored. Neglecting even small differences in attentional skills is especially detrimental in the context of perceptual tasks, which are often not particularly engaging. The specific conclusion with respect to the anchoring deficit is that such a deficit may well exist and might explain poor performance on a certain kind of perceptual tasks, but it is probably not specific to dyslexia.

ACKNOWLEDGEMENTS

REFERENCES

Ahissar, M. (2007). Dyslexia and the anchoring-deficit hypothesis. *Trends in Cognitive Sciences, 11*, 458–465.

Ahissar, M., Lubin, Y., Putter-Katz, H., & Banai, K. (2006). Dyslexia and the failure to form a perceptual anchor. *Nature Neuroscience, 9*, 1558–1564.

Ahissar, M., & Oganian, Y. (2008). Response to Ziegler: The anchor is in the details. *Trends in Cognitive Sciences, 12*, 245–246.

Blomert, L., & Vaessen, A. (2009). *Differentiaal diagnostiek van dyslexie; een cognitieve analyse van lezen en spellen.* [*Differential Diagnosis of Dyslexia*: *A Cognitive Analysis of Reading and Spelling*]. Amsterdam: Boom.

Denckla, M., & Rudel, R. G. (1976). Rapid 'automatized' naming (RAN): Dyslexia differentiated from other learning disabilities. *Neuropsychologia, 14*, 471–479.

Harris, J. D. (1948). Discrimination of pitch: Suggestions toward method and procedure. *American Journal of Psychology, 61*, 309–322.

Kaernbach, C. (1991). Simple adaptive testing with the weighted up-down method. *Perception & Psychophysics, 49*, 227–229.

Mayringer, H., & Wimmer, H. (2003). *Salzburger Lesescreening (SLS 1-4).* [*Salzburg reading screening*]. Bern: Hans Huber.

Nicolson, R. I., Fawcett, A. J., & Dean, P. (1995). Time estimation deficits in developmental dyslexia: Evidence of cerebellar involvement. *Proceedings of the Royal Society of London B, 259*, 43–47.

Ramus, F., Pidgeon, E., & Frith, U. (2003). The relationship between motor control and phonology in dyslexic children. *Journal of Child Psychology and Psychiatry, 44*, 712–722.

Tewes, U., Rossmann, P., & Schallberger, U. (2000). *Hamburg-Wechsler-Intelligenztest für Kinder III (HAWIK-III).* [*WISC-III*]. Bern: Hans Huber.

Willburger, E., & Landerl, K. (2009). Der Ein-Minuten Leseflüssigkeitstest – ein Verfahren zur Diagnose der Leistung im Wort- und Pseudowortlesen. [The One-Minute Reading-Fluency Test—A Diagnostic Instrument for Assessing Word and Pseudoword Reading] In W. Lenhard & W. Schneider (Hrsg.), *Diagnostik und Förderung des Leseverständnisses*: *Tests und Trends (Band 7)*, Jahrbuch der pädagogisch-psychologischen Diagnostik. Göttingen: Hogrefe.

Ziegler, J. C. (2008). Better to lose the anchor than the whole ship. *Trends in Cognitive Sciences, 12*, 244–245.

Zimmermann, P., Gondan, M., & Fimm, B. (2002). *KITAP: Testbatterie zur Aufmerksamkeitsprüfung für Kinder.* [*Test battery for attention assessment in children*]. Herzogenrath: Psytest.