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# Specific auditory training for children with dyslexia and central auditory processing disorder can improve spelling performance

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**Abstract:** Background: In this study, the question of whether auditory training for children with a reading and spelling disorder and a central auditory processing disorder (CAPD) can improve spelling performance is investigated. The training apparatus was the Audiva Company's DichoTrainer. Method: Dichotic discrimination, auditory/kinaesthetic perception and behavioral strengths and peculiarities as well as spelling ability and intelligence were assessed in 36 dyslexic children from years 2 to 4 of primary school with a central auditory processing disorder (CAPD). Subsequently, the children were divided into an auditory training group, a group with a computer-based drill-and-practice spelling PC program (LernReha) and a control group. After a 12-week training period (20 minutes per day), statistically significant improvements in performance were noted. Results: It was shown that improvements in spelling could be documented within the Dicho-Trainer group. A tendency in favor of the auditory training group could be detected in comparison to the spelling training group. As the implementation of the control group was not felicitous, no final conclusion regarding different spelling abilities after training period between Dicho-Trainer group and control-group can be drawn. Conclusions: The results support the assumption that auditory perception ability has an effect on written language. In the group of children experiencing difficulties with auditory perception, not alone can auditory training improve perception, but as a consequence, it can also improve spelling ability.

**Keywords:** Dyslexia, Auditory Perception, Auditory Disorder, Dichotic Hearing, Dicho Trainer

## 1. Introduction

Dyslexia is one of the most common learning disorders. Information about prevalence is inconsistent and (based on the diagnostic criterion and research method), fluctuates between 3 and 15% [see e.g.: 13, 17, 24].

Symptoms of dyslexia often emerge early in school career. During the first school year, there is still a relatively big variance between schoolchildren with respect to their reading and spelling abilities. If clear problems with reading and writing also persist in the second school year, as a rule, children need special care [12]. If dyslexia is untreated, then it often will be a disorder with a poor long-term prognosis. It is considered to be a heterogeneous disorder with causes that have not been fully clarified to date. The discussion centers around genetic and neurological factors primarily as well as the effects of environmental factors.

Auditory perception and processing and in particular phonological awareness have received special attention in the last years with the identification of possible precursors to the acquisition of written language skills [10, 14, 15, 23]. Research results on the link between an auditory perception disorder and dyslexia are not always consistent. Schmidt and co-authors [20], for example, looked into the question as to whether children with or without dyslexia are different in terms of the results of various auditory tests. The results of the dichotic tests were significantly worse for dyslexic children than for the control group. Thus indications of an auditory perception disorder in existing dyslexia were found. [16, 18]. Among others, Suchodoletz et al. [28] found contradictory results.

Auditory training for the treatment of dyslexia was evaluated in various ways. Although effectiveness with regard to the auditory symptoms was found, there are only some reports of effects on reading and spelling ability [4, 8, 19, 29, 30]. The assumption of this study is that, at least for

some of the dyslexic children, difficulties with correct spelling are attributed to a distorted acoustic perception. Thus, improved recognition of spoken language should also improve spelling ability. A supplementary aspect of the research was the effect of training on co-morbid mental abnormalities. Dyslexia can trigger additional mental and disciplinary difficulties. In a series of studies, the connection between specific learning difficulties and mental abnormalities has been shown [1, 9, 13, 24, 25]. If remediation of the primary impairments leads to an improvement of reading and writing, then there should also be a positive effect on emotional problems because the children will experience positive effects of self-efficacy [see e.g. 2].

In the meantime, a multifaceted range of therapies has been established both within the school and outside. Remedial programs with good ratings would be a helpful resource for parents seeking advice. Main problem is that not all therapies focus on the specific reason of the dyslexia.

The DichoTrainer, which was used in this study, is an auditory training device from the AUDIVA company. As is the case in a dichotic hearing test, similar sounding syllables or words are played by this device via headphones in various hearing modes (one after the other, time delayed or simultaneously). Software is available with an extensive selection of groups of similar sounding syllables and monosyllabic or polysyllabic words, which are selected individually and transmitted on the training device. Then, two different items from the selected group will be played randomly in accordance with the set hearing mode. Four response options will be displayed from which the child must select the two words that were heard. For children who can't read adequately, a second headphone can be connected and the response given by the child can be entered by another person. The training time can be scheduled flexibly. After the time runs out, the session will end automatically and the number of correct and incorrect responses is displayed. The device can also be used at home and the children can practice independently, provided they have adequate reading skills.

If reading and writing abilities are significantly improved after the training sessions, it must still be considered whether a training with the DichoTrainer is superior to a direct practice of reading and writing. The dyslexia training-program of LernReha [11] includes more than 7,500 exercises from approximately 50 different problem areas in German spelling. These include exercise areas such as "similar sounding letters" (e.g. p/b and g/k), "doubling" (e.g. f/ff, or m/mm) or "lengthening" (e.g. a/ah or u/uh). Usually, two or three alternative ways of writing a word are presented on the screen. The correct solution is selected by keyboard or mouse.

In addition to a control group with no special therapy, this LernReha program was used in a second group as comparison to ensure that successful acoustic training outcomes can really be interpreted as the result of the acoustic treatment.

# 2. Methods

For this study, children from class 2-4 in primary schools in Luebeck were recruited. Exclusion criteria were the denial of parents or guardians to consent, a first language other than German, hardness of hearing, an acute inflammation of the middle ear, and current participation in a other remedial programmes for dyslexia or irregular school attendance.

In accordance with the class level of the German Spelling Test (DERET 1-2+ and DERET 3-4+, Form A in each case; [26, 27]) and depending on age, the basic intelligence test, CFT 1 or CFT 20-R (the equivalent of the Catell Culture Fair Test, [6, 32]) was used for diagnosis of dyslexia. 1.5 standard deviations (regression criteria) were regarded as a critical difference between writing abilities and intelligence.

Based on the children's age, auditory perception was assessed with the dichotic tests of Uttenweiler [31] or Feldmann [7] (with lengthy pauses) and the Heidelberg Phoneme Discrimination Test (with background noise) [5]. The word pairs in the dichotic tests were provided by headphones at a constant level of 70 dB. In each case, one trial was carried out. A rate of less than 80 percent of correctly repeated word pairs was considered abnormal according to the criteria of Berger & Demirakca [3].

The Heidelberg Phoneme Discrimination Test (H-LAD) items were also presented at 70 dB by means of headphones. If the T-value was below 42 in one of the four subtests or in the total result, it was assumed that there was an impairment of phoneme discrimination ability.

At least one abnormal value in the dichotic test or in one of the test results of the H-LAD was deemed to be a diagnostic criterion for the presence of a central auditory processing disorder. In accordance with the aforementioned criteria, an auditory perception disorder was detected in 39 of 42 investigated children with suspicion of problems of acoustic differentiation and an existing spelling difficulty.

In order to ascertain any abnormalities in the behaviour of the children, a German version of the Strengths and Difficulties Questionnaire (SDQ-D), was used.

Three children did not participate in the study, so that N=36 children from 18 different Luebeck primary schools were included in the investigation. The proportion of girls (11) and boys (25) corresponded to a gender ratio of 1: 2.27. This was consistent with the generally reported over-representation of boys. The average age was 8.67 years (SD = 1.12; min. = 7 and max. = 11), the average IQ was 103.4 (SD = 11.9, min. = 85 and max. = 126).

The children who participated were randomly assigned to the Dicho-Trainer group (6 girls and 6 boys), the control group (2 girls and 10 boys) or the LernReha group (3 girls and 9 boys). Table 1 provides a summary of the distribution of average IQ, spelling ability and auditory abilities.

The average results of the SDQ at the first measuring time, the corresponding cut-off values for behavior to be classified as borderline and the extreme values beyond the groups can be seen on Table 2.

Total, in the initial SDQ assessment in average some high

values are found in the areas of emotional problems (M = 3.39), behavioral problems (M = 2.39) and behavioral problems with children of the same age (M = 2.31). For 26 children there was at least one raised result.

The parents and children of the experimental group and the LernReha group received individual instructions on the device and the program and a practice schedule. The practice exercises were made with an increasing degree of difficulty and were identical for all children in the particular group.

***Tab 1.*** *Pretest-results „IQ", „spelling abilities" and „auditory abilities"*

| | | total | 1. group Dicho | 2. group Lernreha | 3. group control |
|---|---|---|---|---|---|
| IQ | M SD | 103,40 ± 11,87 | 102,50 ± 14,82 | 100,58 ± 13,00 | 107,08 ± 5,98 |
| DERET | M SD | 4,69 ± 4,71 | 5,00 ± 5,48 | 5,67 ± 5,43 | 3,42 ± 2,84 |
| Dichotisch | M SD | 46,44 ± 22,21 | 41,17 ± 22,26 | 46,50 ± 19,09 | 51,67 ± 25,48 |
| H-LAD 1 | M SD | 48,86 ± 10,70 | 45,42 ± 9,55 | 48,00 ± 6,30 | 53,17 ± 14,14 |
| H-LAD 2 | M SD | 46,75 ± 11,27 | 43,58 ± 13,75 | 48,58 ± 7,98 | 48,08 ± 11,60 |
| H-LAD 3 | M SD | 47,72 ± 13,07 | 44,50 ± 11,22 | 46,08 ± 11,74 | 52,58 ± 15,48 |
| H-LAD 4 | M SD | 48,00 ± 10,49 | 44,58 ± 10,38 | 48,50 ± 8,23 | 50,92 ± 12,33 |

Over a period of 12 weeks a 20-minute daily training was prescribed. The time of the training was at the convenience of the children.

Before the study began, the consent of the competent school boards, the education department of the Hanseatic City of Luebeck and the relevant school principals was obtained. Parents were given detailed information about the background and implementation of the study. The study design was approved by the ethics committee of the University of Luebeck (Ref.: 08-232) and was in accordance with the regulations stated in the Declaration of Helsinki.

## 3. Results

Tests were conducted for the normal distribution of variables (Kolmogorov-Smirnov-test) and for homogeneity of variance (Levene test). None of these results were significant. Due to the relatively small size of the groups, variance analysis was used to check whether differences between the three groups exist before the training. No significant group differences were shown at the level of 20% for intelligence or dyslexia and auditory perception ability.

The main goal of our study was the evaluation of significant increases in performance in auditory perception and spelling ability and a decrease of behavioural abnormalities in the (a) DichoTrainer group and (b) in the LernReha group compared with (c) a control group. For this reason, auditory perception ability (Uttenweiler/Feldmann and the Heidelberg Phoneme Discrimination Test H-LAD), spelling ability (DERET, Form B) and the Strengths and Difficulty Profile (P4-16 - SDQ) were assessed again after the 12 weeks of training.

In the Dicho-trainer group, clear improvements were shown for auditory perception performance as well as for spelling ability. Performances in dichotic hearing ($t_{(11)}$ = -6.594, p = .000), in the correct auditory responses ($t_{(11)}$ = -3.378, p = .003), in the correct kinaesthetic responses ($t_{(11)}$ = -2.997, p = .005) and in the total H-LAD ($t_{(11)}$ = -3.555, p = .0025) were significantly increased. By contrast, the ability to analyse sound was not improved ($t_{(11)}$ = -1.001, n.s.). Spelling ability levels were also significantly better after the training phase than they were before the training ($t_{(11)}$ = -3.867 and p = .0015). Performance levels before and after the training are presented in Figures 1 - 3.

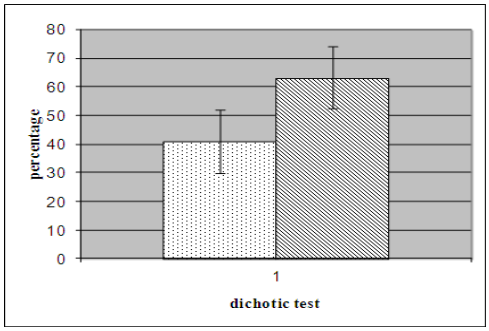


***Figure 1.*** *percentage of correct word-pairs (light bar = baseline, dark bar = final outcome)*

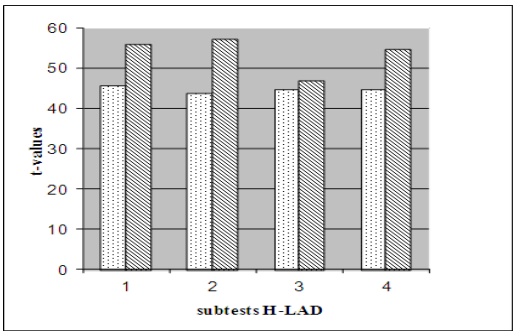


***Figure 2.*** *T-values of 4 subtests of H-LAD (light bar = baseline, dark bar = final outcome)*

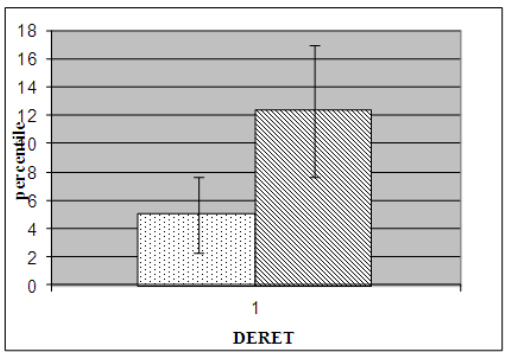


***Figure 3.*** *percentile of DERET before (light bar) and after training (dark bar)*

The difference of the percentiles in the DERET as an expression of the increase in performance was 7.33 (min. 0 and max. 16) on average.

Significant improvements could only be determined for the SDQ in behavioural problems with peers of the same age ($t_{(11)}$ = 2.548 and p = .014). No other tests results were significant (see Figure 4).

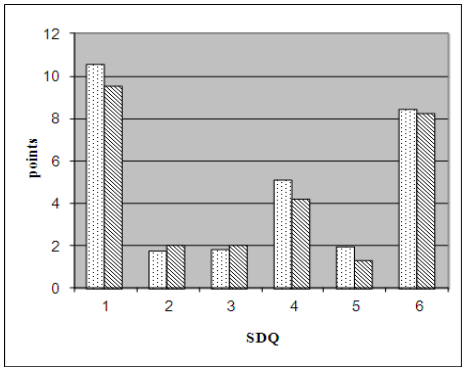


***Figure 4.*** *results of SDQ (light bar = baseline, dark bar = final outcome)*

The children in the Dicho Trainer group demonstrated a significantly better performance in the Uttenweiler or Feldmann tests than the children in the LernReha group ($t_{33}$ = 2.367 and p = .012) and in the control group ($t_{33}$ = 3.110 and p = .002).i

Analyses of variance for the Heidelberg Phoneme Discrimination Test (H-LAD) and its subtests produced significant group differences for the *correct auditory responses* ($F_{2,33}$ = 4.349, p = .021) and *correct kinaesthetic responses* ($F_{2,33}$ = 3.605 and p = .038). The comparison of groups with respect to the *total H-LAD* merely indicate a trend ($F_{2,33}$ = 2.844 and p = .073). The differences in *sound analysis* were not significant ($F_{2,33}$ = 1.069, n.s.).

Contrast analyses resulted in an increase in performance in the DichoTrainer group for the *total H-LAD* in comparison to the control group ($t_{33}$ = 2.337 and p = .013). Comparing the Dicho Trainer and the LernReha group, only a trend in favour of the experimental group was found ($t_{33}$ = 1.581 and p = .062).

Comparing the baseline and follow-up results of spelling ability, shows that performance improved in all three groups (see Figure 7).

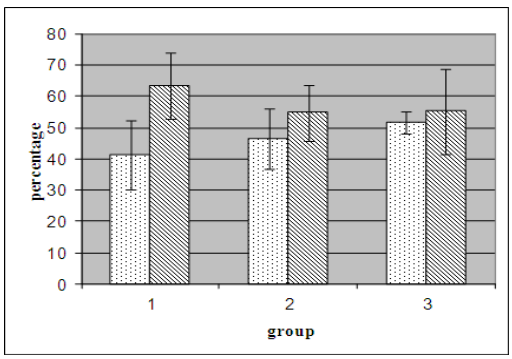


***Figure 5.*** *correct word-pairs in 1= Dicho-Trainer, 2 = LernReha, 3 = control (light bar = baseline, dark bar = final outcome)*

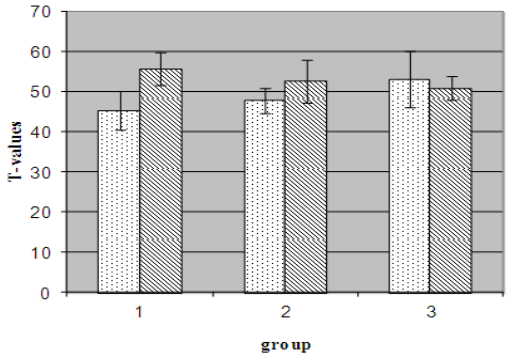


***Figure 6.*** *T-values H-LAD (auditory) in 1= Dicho-Trainer, 2 = LernReha, 3 = control (light bar = baseline, dark bar = final outcome)*

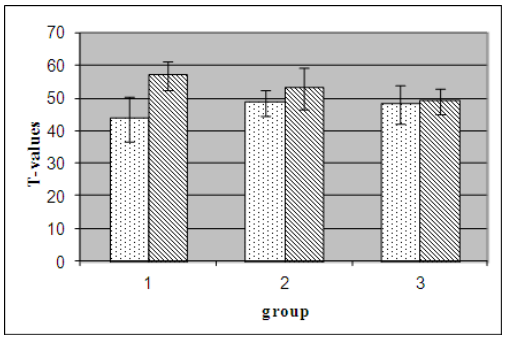


***Figure 7.*** *T-values HLAD 2.*

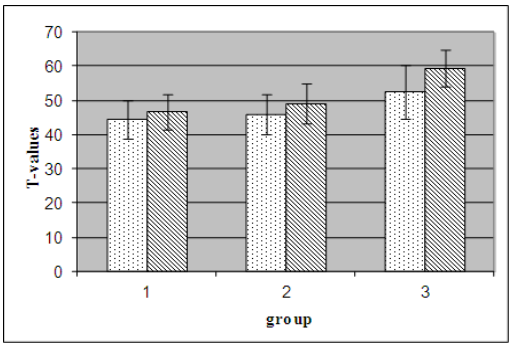


***Figure 8.*** *T-values H-LAD 3 (sound analysis)*

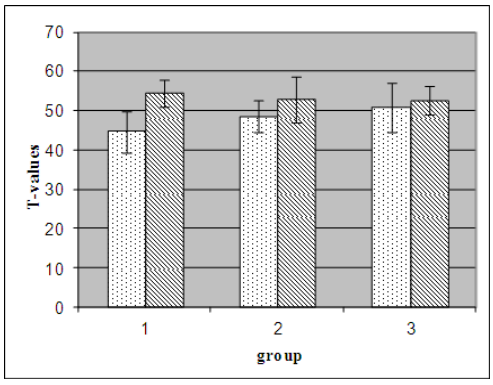


***Figure 9.*** *T-values H-LAD 4 (total)*

Children's age was included as a covariate in an ANOVA in the comparison of spelling ability results. In total, a 23.3% model (corr. 16.1%) explains the variance ($R^2$ =.233). The explanation of the variance by this model is significant (F =

3.234, p = .035). However, neither age (F = 1.507, n.s.) nor group membership (F = 2.094, n.s.) have had a clear significant effect. The calculation of contrasts with the Dicho Trainer group as the reference group for comparison of the LernReha group to the Dicho Trainer group indicated a trend in favour for the Dicho Trainer group (t = -5.38 and p = .053). The comparison of the control group to the Dicho Trainer group was not significant (t = -1.287, n.s.). Figure 8 shows the differences in the percentiles before and after the training.

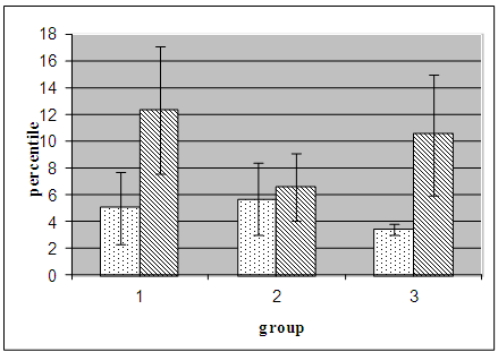


***Figure 10.*** *percentile of DERET*

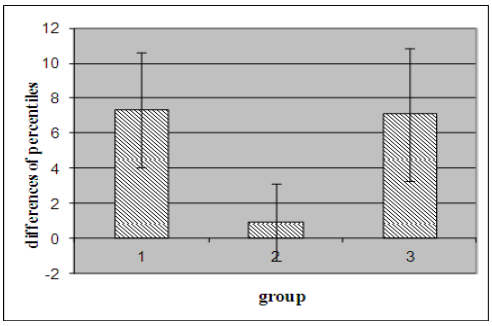


***Figure 11.*** *differences of percentiles DERET ($T_2$-$T_1$)*

Contrary to expectations, the analysis of spelling ability showed distinctly better results not only for the experimental group, but also for the untreated waiting group. A possible explanation was that these children had participated in other trainings due to the diagnosis of this investigation. Therefore an anonymous follow-up survey was made, which showed that 8 children at that time had participated in at least one remedial activity. These activities ranged from extra-curricular trainings for dyslexia at school, speech therapy and more private activities. Evidently, after the diagnosis of a reading and spelling disorder, the pressure to do something for their children was too great for parents to stand idly by for a period of three months. With respect to future studies, the question is raised as to whether such a control group can really be implemented.

# 4. Discussion

First of all, it must be determined that, of the 42 children with dyslexia, 39 also had a central auditory processing disorder. However, as no comparison was carried out with children, whose spelling was within the normal range, this study cannot contribute to the clarification of the controversial issue as to whether a a central auditory processing disorder (CAPD) is found more often in children with dyslexia, than in children without this problem (see [see e.g.: 16, 20, 30].

Auditory performance was surveyed using different parameters. Significant progress in performance was revealed for dichotic hearing in the auditory and kinaesthetic perception performance of the H-LAD. Only the ability to analyse sounds could not be improved.

Training with the DichoTrainer in the form in which it was implemented here, aimed at correctly identifying similar sounding pairs of words that were presented dichotically. The tests by Uttenweiler and Feldmann showed an improvement in performance in the dichotic hearing tests.

The positive results are consistent with study results that were able to show basically that it is possible to practise auditory functions. Comparison is problematic because in the various studies, different areas of auditory perception were measured and practised. Whereas linguistic stimuli were presented in the here present study, other studies used speech-free stimuli [4, 8]. Similar outcomes when different training materials are used, could be an indication that training effects must be achieved independently of the kind of auditory stimuli presented. However, it remains unclear as to whether improved perception ability is only to be found in the areas that are directly practised or whether it is generalised to other areas of auditory perception.

For the involved children and their parents, the effect of training on spelling ability is of particular significance. Improvement could be substantiated in this regard. For the experimental Dicho-trainer group, a significantly improved performance was shown, so that we can assume that there is a transfer to writing abilities.

Improvements on behavioural problems could not be documented. Perhaps, a training period of 12 weeks was too short to have an impact on other mental disturbances..

The superiority of the auditory training programme in comparison to the LernReha programme could be demonstrated for auditory perception ability in almost all areas and for spelling ability in a clear trend. While such a daily practice with a universal computer software may help many children, it is not specific enough for children with auditory deficits, which leads us to the conclusion that, before any therapy is done, one first mast have a look to possible causes of the dyslexia.

Further optimising of the effects of an auditory dyslexia-training must consists an individualising of exercise programmes. To safeguard comparability of study results, all of the children here received an identical training programme, which was not geared to individual problem areas.

Some completely positive effects have been shown on average in this study. However, an improved performance was not to be determined for all of the children in the

experimental group. An examination of the extent, to which children with or without successful training are different, could be the subject of a future study.

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