LOW-LEVEL AUDITORY FUNCTIONS AND MUSICAL APTITUDE

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ABSTRACT

Background. Most recently the correlation between low-level functions (LLFs) in the auditory domain - such as pitch discrimination, order threshold, spatial hearing, pattern identification and language proficiency - has become the topic of research. Latest findings indicate that impaired LLFs might be a major cause of dyslexia. It was shown that training impaired LLFs in dyslexic children significantly improved their spelling scores as compared to controls undergoing conventional remedial teaching.

Aims. It was hypothesized that a similar correlation might exist between certain LLFs and musical aptitude. If such a correlation exists it could be utilized in two ways: First, in order to envision possible musical talents at an early stage of life; second, in order to improve musical education by ameliorating those LLFs in which students show deficiencies.

Method. In a group, which included 392 children, age 5 through 12 years (152 of which played a musical instrument), the following seven LLFs in the visual, auditory and motor domains were assessed:

- 3.1 Visual order threshold
- 3.2 Auditory order threshold
- 3.3 Spatial hearing
- 3.4 Pitch discrimination
- 3.5 Auditory motor timing
- 3.6 Auditory choice reaction time
- 3.7 Frequency pattern test

Results. In four LLFs, the group of 152 playing an instrument achieved significantly better scores than the controls of 240 children playing no musical instrument, namely auditory order threshold, pitch discrimination, auditory motor timing, and frequency pattern test.

Conclusions. So far, the results seem to lead us to the chicken-egg-question: They suggest that either highly developed LLFs improve musical proficiency or that musical proficiency improves LLFs. A third possibility might be a reciprocal facilitation of both. Further studies will be necessary to decide which of the three is most likely to occur.

1. BACKGROUND

The term "low-level-functions" refers to basic functions in all sensory domains. In a study with preschool and elementary school children, Tewes (2001) *et al.*, showed that seven impaired low-level functions could be trained by using combined audio-visual cues in conjunction with audio-visual reinforcement. Within 25 training sessions over a period of five weeks, the training group achieved standardized results, whereas the control group without this special training remained far behind.

In a comparative study with three German elementary schools, Tewes (2003) *et al.* showed that there was a marked difference between students with dyslexia and a control group as far as seven low-level functions are concerned in the visual, auditory and motor domains. Furthermore, the impaired low-level functions could be improved significantly by 48 hours of training. Finally, the trainings groups also improved their spelling scores significantly as compared to control groups undergoing conventional remedial teaching.

2. AIMS

According to Ptok (2000), there are five levels of language proficiency, which he first presented in conjunction with presumed causes of dyslexia:

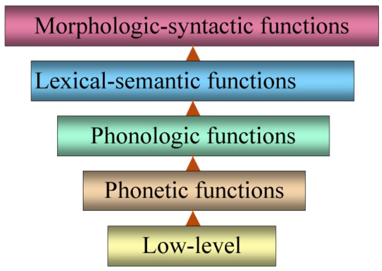

Figure 1: Five levels of language proficiency

Ptok claims that sufficient proficiency at lower levels is a prerequisite for achieving satisfactory performance at higher levels. A complementary study by Buller (2001) *et al.* actually showed a correlation between low-level functions and the phonological level, i.e. a group of children with impaired low-level functions also had phonological deficits. Schneider (2001), on the other hand, showed that deficiencies on the phonological level with preschool children are predictors for dyslexia after these children will have started their school careers, and that training impaired phonological functions at preschool age reduces the risk for these children of becoming dyslexics. Thus, low-level disorders seem to cause deficits all the way up to the morphologic-syntactic level.

So it was hypothesized that a similar correlation might exist between certain LLFs and musical aptitude. If such a correlation exists it might be utilized in two ways: First, in order to envision possible musical talents at an early stage of life; second, in order to improve musical education by ameliorating those LLFs in which students show deficiencies.

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3. METHOD

In a group, which included 392 children, age 5 through 12 years (152 of which played a musical instrument), the following seven LLFs in the visual, auditory and motor domains were assessed:

1.1. Visual Order Threshold

The visual order threshold is the smallest time interval between two brief visual cues that a subject can both distinguish and locate into a proper sequential order. It is measured by presenting two flashes of light by means of light emitting diodes (LEDs) spaced 45 mm apart and looked at by the subject tested from a distance of 40 cm. Using a stepladder algorithm the individual visual order threshold, starting with an inter stimulus interval (ISI) of 400 ms, is ascertained.

3.2. Auditory Order Threshold

The auditory order threshold is the smallest time interval between two brief auditory stimuli that a subject can both distinguish and put into a proper sequential order. It is measured by presenting two noise bursts of 5 ms in a pair of headphones with either the left or the right ear leading. Using a stepladder algorithm the individual auditory order threshold, starting with an ISI of 400 ms, is determined.

3.3. Spatial Hearing

Spatial hearing is the ability to determine the direction from which an auditory phenomenon is heard. To ascertain the spatial hearing acuity of a subject in the horizontal plane two clicks are presented in a pair of headphones with either the left or the right ear leading which is less than the fusion threshold apart. Using a stepladder algorithm the individual spatial hearing resolution, starting with an ISI of 280 µs, is established.

3.4. Pitch Discrimination

Pitch discrimination is the ability to distinguish between two tones with different frequencies and to determine their sequence. The two tones are presented in a pair of headphones monaural. The subject tested has to indicate the time order of the two tones. Using a stepladder algorithm the individual pitch discrimination threshold, starting at 40%, is ascertained.

3.5. Auditory Motor Timing

Auditory motor timing is the ability to synchronize a regular alternate finger tapping with a left-right clicking pattern heard in a pair of headphones. Each time the tapping coincides with the clicking pattern the speed is slightly increased, i.e. the ISI is continuously reduced. After 40 seconds the subject tested will have reached his/her maximum synchronized tapping speed.

3.6. Auditory Choice Reaction Time

Auditory choice reaction time is the interval between an auditory task leaving at least two reaction choices. It is measured by presenting two tones in a pair of headphones with either the left or the right ear leading. The subject tested has to determine whether the lower tone was heard from the left or from the right. After 40 repetitions the average response time is calculated.

3.7. Frequency Pattern Test

Here the ability to recognize small differences in a suite of tones and to distinguish them is tested. The subject tested will hear a succession of three tones, two of which are identical and one is different. The position of the deviation tone – whether in first, second or third position – has to be indicated. Using a stepladder algorithm the individual frequency pattern threshold, starting at 400 ms for tone length and for ISI length, is ascertained.

3.8. Test Equipment Used

TEST:
www.brainboy.de

Figure 2: Brain-Boy-Universal

The hand-held unit called “Brain-Boy-Universal” is powered by a 9-Volt-Battery and needs 3 push buttons to select any of the 7 test procedures. The operator can follow up on the results of the subject tested by means of the elaborate feedback information in the display. Both timing and generation of the required frequencies are accomplished by a microprocessor. A pair of headphones is connected to the device.

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4. RESULTS

Table 1 depicts some of the results, which shows a steady improvement as a function of age.

Age	Visual order threshold	Auditory order threshold	Spatial hearing	Pitch discrimination	Auditory motor timing	Auditory choice-reaction time	Frequency pattern test
Years	ms	ms	µs	%	ms	ms	Ms
5	160	260	157	50	528	354	575
6	108	190	122	39	487	321	405
7	63	136	95	31	444	293	300
8	47	99	74	24	403	260	220
9	41	83	59	21	372	238	162
10	38	73	49	21	345	205	142
11	36	68	43	21	316	183	116
12	35	65	39	21	292	162	116

Table 1: Mean standard scores of 382 Children in seven tasks

The main question, however, in the context of this study, was whether there is a marked difference in the performance of children playing a musical instrument and those who do not. As a result, the mean standard scores of the two groups were compared with each other as shown in Table 2.

Variable	♩	n	mss	sd	t	p
Visual order threshold	No	241	.0137	0,98	0.20	.840
	Yes	152	-.0337	0.91		
Audit. order threshold	No	242	.0368	1.03	2.29	.023
	Yes	152	-.1971	0.92		
Spatial hearing	No	240	.0452	1.02	0.95	.344
	Yes	152	-.0545	1.01		
Pitch dis-crimination	No	242	.2244	0.87	5.39	.000
	Yes	152	-.2758	0.94		
Auditory motor timing	No	242	.1338	0.96	3.72	.000
	Yes	152	-.2243	0.88		
Auditory choice react.	No	242	.0514	0.99	0.07	.943
	Yes	152	-.0439	1.06		
Frequency pattern test	No	242	.2704	0.97	6.42	.000
	Yes	152	-.2243	0.93		

Table 2: Comparison of mean standard scores between groups

It is obvious that only three of the seven tests are not significantly influenced. These are the visual order threshold with p = 0.840, spatial hearing with p = 0.344, and the auditory choice-reaction time with p = 0.943. On the other hand, however, the remaining four parameters show highly significant deviations between the two groups ranging from p < 0.000 to p = 0.023 in favor of those children playing a musical instrument. They are:

- Auditory order threshold
- Pitch discrimination
- Auditory motor timing
- Frequency pattern test

5. CONCLUSIONS

So far, the results seem to lead us to the chicken-egg-question: They suggest that either highly developed LLFs improve musical proficiency or that musical proficiency improves LLFs. A third possibility might be a reciprocal facilitation of both. Further studies will be necessary to decide which of the three is most likely.

Therefore, we shall focus our attention on the probable contributions between the above four parameters and musical aptitude and vice versa:

5.1. Auditory Order Threshold

The auditory order threshold continuously segments the incoming stream of audio signals into chunks of a few tenth of a millisecond. The smaller the auditory order threshold is the finer the perception of the individual is prearranged for sound that is highly structured in the time domain. Since transients of many musical instruments are also located in the range of a few tenth of a millisecond a fast auditory order threshold lends itself for a minute recognition of these important structural details.

5.2. Pitch Discrimination

The interdependence between pitch discrimination and musical aptitude is especially important for those instruments which demand a continuous monitoring of the tones actually produced, i. e. all string instruments and most wind instrument. Meyer (1979) tested various professional and non-professional groups of musicians. He found that 67% of the string players tested could distinguish frequencies differing by only 0.4%. They were only surpassed by sound recording engineers who reached this goal by 100%. Following in rank order were guitar, piano, recorder, accordion players and choir singers.

5.3. Auditory Motor Timing

Auditory motor timing and its correlation to dyslexia was repeatedly the topic of Wolff (1984) and Wolff (1993). His findings suggest that one major source of difficulties in motor performance may be in rapid communication between the hemispheres which is essential for both reading and orthographic proficiency. Apparently, this necessity of rapid communication between the hemispheres also plays an important role in musical proficiency.

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5.4. Frequency Pattern Test

Musiek (1980) found a correlation between the results of his frequency pattern test and language proficiency in children. This test actually represents a successful combination of skills both in the frequency and the time domains. This is reflected in the highest t-value of 6.42 in table 2. In playing any musical instrument this mixture is imperative.

5.5. Implications

As far as the authors know the tests of musical aptitude prevailing today are based on Gordon's model of Audiation. Reverting to Figure 1 with the five levels of language proficiency and presuming that there is a comparable hierarchy also in music, it seems as though Gordon's preference is focused on higher levels rather than on low-level functions.

We, therefore, suggest that future research in this field should direct its attention from low-level functions all the way up to the top. Thus basic and intermediate deficiencies could be detected at an early age. Since it has been proven that low-level-functions can be trained in a few weeks (Tewes 2001 *et al.*) there is no plausible reason to withhold this opportunity to children and adults regardless of whether they intend to play an instrument or not.

The Brain-Boy-Universal depicted in Figure 2 is not only designed for *testing* these seven low-level-functions but also for *training* them utilizing the German Patent 196 03 001 „Vorrichtung zum unterstützten Trainieren und Lernen“**:** By using visual cues during the latency between task und reply the child actually improves its low-level functions in an amazingly short time.

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