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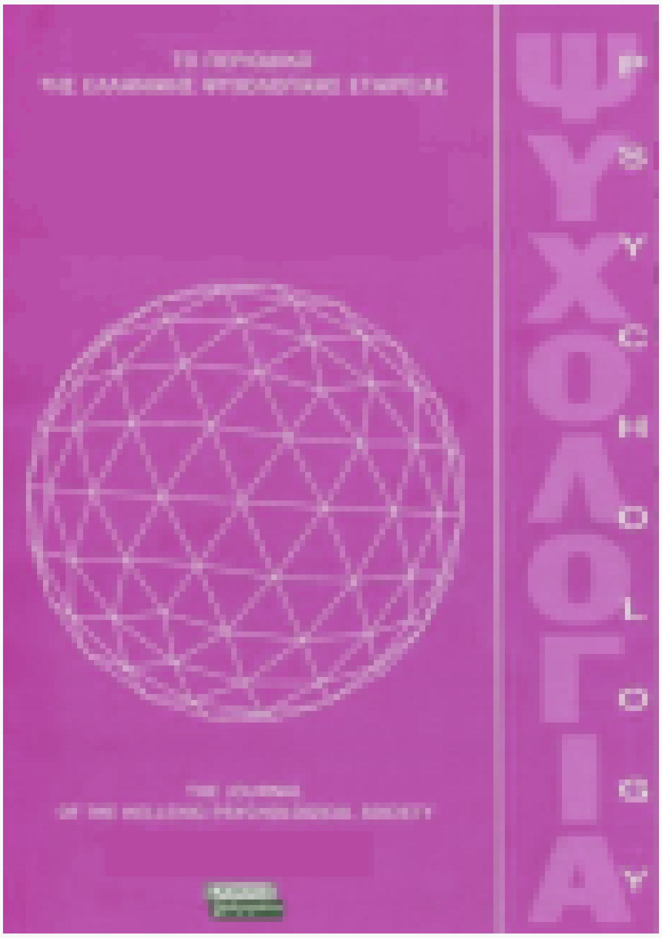

Auditory and linguistic abilities among children with phonological problems

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Auditory and linguistic abilities among children with phonological problems

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ABSTRACT The aim of the present study was to find out whether auditory and linguistic problems are more prevalent among pupils with phonological problems than in the normal population. Nineteen pupils with phonological difficulties and 19 controls took part in this study. Participants were matched for grade level (pupil years) and gender. Two standardized tests of phonological ability were used in the sampling. The pupils with phonological problems had a combined z-score of -1.5 or lower. Each of the controls had a combined z-score of zero or higher. A paired samples t-test was used to compare the auditory and linguistic skills of the two groups. On all the tests we found that the experimental group scored significantly lower than the control group. Inappropriate use of attention is suggested as a possible common factor underlying auditory, phonological, and general linguistic problems.

Keywords: Attention problems, Auditory problems, Phonological problems.

Introduction

It has long been known that the hearing impaired usually read less well than people with normal hearing. Some studies indicate that reading problems increase in proportion to hearing impairment (e.g., Dodd, 1980; Hanson, 1989; Jensema, 1975; King & Quigley, 1985; Wrightstone, Aronow, & Moskowitz, 1963). These and other studies also show, however, that there are some people with hearing problems who read almost normally.

It is a well-established fact that hearing impairment can lead to difficulties in phonological, semantic, and syntactical skills (cf. Bamford & Saunders, 1991; Burden & Campbell, 1994; Strassman, 1992). Obviously, learning the repertoire of grapheme-phoneme associations needed in decoding and reading is very difficult for children who lack correct phonemic identities in long-term memory. Lack of phonemic identities can further impair the grasp and storing of both content words and function words correctly, which in turn may impact negatively on these pupils' semantic and syntactical skills.

There is far less support for the opposite assertion, namely that most pupils with reading problems also have some form of hearing impairment. In the last 10 to 20 years Paula Tallal, most prominently, has made this claim (Tallal, 1980, 1984, 1990; Tallal, Miller, Bedi, Byma, Wang, Nagarajan, Schreiner, Jenkins, & Merzenich, 1996; Tallal & Piercy, 1974). For Tallal, however, pupils with reading problems have a hitherto unnoticed form of hearing impairment involving problems in perceiving

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small nuances of speech, in particular the very rapid changes in sounds we find in conjuction with consonants.

Tallal and her co-workers claim that these auditory problems are not only found among dyslexics, but also among the larger group they call the "language learning impaired" children (LLI). As support for their claim that auditory problems are the root cause of language problems, they point to their results in training pupils in auditory discrimination. This training, they claim, leads to an improvement of the pupils' linguistic skills (Tallal et al., 1996). Both Tallal's results and her interpretation of them have been strongly criticised by, e.g., Libermann and his co-workers (e.g., Mann & Liberman, 1983; Mattingly, Liberman, Syrdal, & Halwes, 1971. For overview, see Farmer & Klein, 1995; Studdert-Kennedy & Mody, 1995). These critics point out that auditory and phonological phenomena are essentially different. Language-sounds have to be perceived categorically (as phonemes), while other sounds can be perceived as a continuum.

A number of other questions and objections to Tallal's work have also been raised (cf. Toennessen, 1999). Moreover, several serious methodological deficiencies in Tallal et al.'s empirical studies have been pointed out. The samples they have used have been very small and unclearly defined, which makes it difficult to ascertain how representative the results are. Their studies often lack control groups, or use control groups that are sampled incorrectly. Inadequate or unclear descriptions of their tests and methods have also contributed to the nearly total lack of replication of Tallal et al.'s results.

In the present study we will firstly try to determine whether there are any significant differences between the experimental group and the controls in their ability to perceive pure tones. Then we will try to answer the question of whether the groups show significant differences in some specific linguistic abilities. Instead of attempting an exact replication of Tallal and co-workers' studies, we have rather chosen our own instruments and methods which we hope will throw light on the relationship between phonological problems and pupils' grasp of pure sounds and language sounds.

Method

Design and participants

Paula Tallal and her co-workers have studied the auditory skills among a relatively broadly defined and only vaguely delimited group of LLI children. Even though the LLI group was somewhat heterogeneous, the phonological difficulties do seem to have been an important common denominator. When selecting our experimental group we chose to concentrate on children's phonological difficulty (cf., Toennessen, 1997 on definitional issues). There is a number of tests that are considered to measure phonological ability. Of these we have chosen two, which we regard as central to our understanding of phonological skill. These tests are the Reading of Nonwords and the Homophonic Nonword Decision Test, which are described in the Instruments chapter.

Our experimental group consisted of 19 pupils who had a composite score of $z = -1.5$ or lower on the two phonological tests mentioned above, i.e., the mean of the two scores was -1.5 *SD* or below. Our control group consisted of 19 pupils matched with the experimental group for grade-level and gender (see Table 1). This matching was done because we wanted to control for these two variables which have shown to be important in previous studies. Each of the control group members had a composite score on the two tests of $z = 0$ or better. Regarding the sampling variable "phonological ability", we tried to find experimental and control groups that were as homogeneous as possible and whose means differed by at least 1.5 *SD*.

Table 1
Distribution of gender and grade level in the experimental group and control group.

Grade level	Age	Gender
4th grade	approx. 10 years	6 boys and 4 girls
5th grade	approx. 11 years	2 boys and 1 girl
6th grade	approx. 12 years	3 boys
7th grade	approx. 13 years	2 boys and 1 girl

Instruments

A. Sampling tests and procedures

The two tests of phonological skills we used for the sampling procedure have been standardized for these age groups, and they are part of a comprehensive personal computer-based series of tests developed by Høien and Lundberg (1991). The two specific tests are:

Sampling Test 1: Reading of nonwords. This test is carried out on a personal computer. It consists of 36 nonwords. The nonwords appear one at a time on the screen. The pupil is asked to read aloud the word as quickly as possible. The test-giver registers whether the nonword is read correctly or incorrectly, while the computer registers the number of seconds from the appearance of the nonword on the screen until the test-giver presses a key on the keyboard immediately after the pupil has answered.

Sampling Test 2: Homophonic Nonword Decision test. This test is also carried out on a personal computer. It consists of 40 pairs of nonwords. In each of the pairs, one of the nonwords is constructed so as to yield the pronounciation of a common (i.e., high frequency) real word. An example in English would be *fite* (homophone to *fight*). The other nonword in the pair is constructed to be readily pronouncable, but the phoneme string it yields is not a word. Examples in English would be *leat, libe, masp.* The nonwords appear on the screen in pairs, one pair at a time. The pupil is asked to press one key if the homophonic nonword is on the left, and another key if it is on the right. The computer registers the number of correct responses and the time (in seconds) the pupil uses in answering.

On Sampling Test 1 we registered the following differences of means between the experimental group and the control group: -4.72

Table 2
Results on Sampling Test 1 for experimental group and control group. Accuracy (the number of correct responses) and latency are recalculated as z-scores

Test 1	Group	*N*	Min.	Max.	Mean	*SD*
Accuracy	Experimental	19	-11.9	0.2	-3.80	3.04
	Control	19	0.1	1.3	0.92	0.37
Latency	Experimental	19	-4.9	-0.4	-2.12	1.16
	Control	19	-0.2	2.2	1.12	0.65

Table 3
Results on Sampling Test 2 for experimental group and control group. Accuracy (the number of correct responses) and latency are recalculated as z-scores

Test 2	Group	*N*	Min.	Max.	Mean	*SD*
Accuracy	Experimental	19	-5.9	1.4	-1.20	1.56
	Control	19	-1.4	1.4	0.47	0.78
Latency	Experimental	19	-17.1	-2.1	-6.69	3.28
	Control	19	-2.5	1.6	0.41	0.95

on accuracy (SD = 2.98) and -3.24 on latency (SD = 1.26). Paired t-tests yielded significant results on both differences, $t(18) = -6.89$, $p = 0.00$ for accuracy and $t(18) = -8.97$, $p = 0.00$ for latency (see Table 2).

On Sampling Test 2 (see Table 3) we registered the following differences of means between the experimental group and the control group : -1.67 on accuracy (SD = 1.68) and -7.10 on latency (SD = 3.25). Paired t-tests yielded significant results on both differences, $t(18) = -4.31$, $p = 0.00$ for accuracy and $t(18) = -9.52$, $p = 0.00$ for latency.

B. Auditory and linguistic tests

Audiometric tests. This testing was carried out with a standard electronic tone-generator and a headset. We registered the participants' threshold for perceiving pure tones of the frequencies 500, 1000, 2000, 3000, 4000, and 6000 Hz. The signals were presented to each ear separately. We sought to ascertain the lowest amplitude (in decibel) that the participants could reliably hear with each ear. Zero dB is baseline for a person aged 18 to 25 yrs. Sounds below this amplitude are expressed in negative dB. In screening studies normal hearing is often put at 15 dB, yet even a threshold at 25 dB is considered within the normal range.

The Illinois Test of Psycholinguistic Abilities subtests. In their sample of language learning impaired children, Paula Tallal and her co-workers found semantic, syntactical and articulation problems. In their discussion it seems as if they trace these problems back to some underlying phonological difficulties, which they in turn trace back to auditory problems. Their implicit claim —that there is a cascade of problems all derived ultimately from auditory problems— is the reason we wanted to see if we could find a connection between our participants' phonological difficulties and any possible broader problems with language. We opted not to give to the participants a full psycholinguistic test battery, but rather to use seven subtests of The Illinois Test of Psycholinguistic Abilities (ITPA) that seem relevant to our purpose. The theoretical basis of the ITPA is discussed in McCarthy and Kirk (1963) and Kirk and Kirk (1971). The standardized Norwegian version we used is discussed in Nygaard (1975). We used the following subtests of ITPA:

1. *Auditory reception.* This test measures the ability to understand the semantic meaning of auditory language stimuli. There are 50 yes/no questions of the type: Can tomatoes talk?

2. *Auditory association.* It measures the ability to organize and relate auditorily received stimuli to systems of concepts established in the long-term memory. There are 42 incomplete sets of analogies such as: Lemons taste sour; sugar tastes - - - .

3. *Verbal expression.* The purpose of this test is to measure how well the pupil expresses

concepts in speech. The pupil is shown a number of objects, such as a ball or a wooden block, and is asked to say everything he or she knows about it. Points are given in each of 10 possible categories of concepts.

4. *Grammatical closure.* This is a test of how well the pupil is able to utilize the representational nature of spoken language and its redundancies. Twenty-eight drawings are presented individually with one or more statements about each one. An important part of one of the statements has been left out. The pupil is asked to complete the statement. The context permits the pupil to spontaneously supply the missing part in its correct grammatical and syntactical form if he or she has sucessfully automatized this ability.

5. *Auditory sequential memory.* Sequences of digits are read aloud at the rate of 2 digits per second. There are 28 sequences varying from 2 to 8 digits in length. The pupil is asked to recall the sequence immediately.

6. *Auditory closure.* It measures the ability to spontaneously recognize an orally presented word in which one or more phonemes have been left out. There are 30 items of increasing difficulty.

7. *Sound blending.* The phonemes of a word are presented orally at the rate of 2 per second in the correct order. The pupil is asked to blend the sounds together to make the word. There are 32 words of increasing difficulty.

Results

The experimental and control groups were matched in pairs for grade-level and gender. We have therefore used a paired-samples t-test for each of the subtests in order to find any significant differences between the groups. Such differences would indicate that these two groups did not only differ in phonological skills but also in auditory and linguistic skills.

Audiometric tests. The tests were done with one frequency at a time. We sought the lowest amplitude in dB at which the person could hear a tone. Our results are reported as mean scores corresponding to frequencies:

Frequency 1: 500, 1000, and 2000Hz
Frequency 2: 1000, 2000, and 3000 Hz
Frequency 3: 4000 and 6000 Hz.

Thus, each pupil was given a score for each of the frequency groups, the score being the average of the threshold dB needed for each of the frequencies in that group. Table 4 presents the data for the left ear and Table 5 for the right ear.

Left ear. On the left ear audiometric tests we obtained the following differences of means between the experimental group and the control group: Frequency 1: 4.74 (SD = 8.30, $t(18)$ = 2.49, p = 0.02), Frequency 2: 3.94 (SD = 7.96, $t(18)$ = 2.41, p = 0.03), Frequency 3: 12.43 (SD = 10.45, $t(18)$ = 4.65, p = 0.00).

Table 4
Experimental and control groups' audiometric results, left ear (in dB)

Test	Group	*N*	Min.	Max.	Mean	*SD*
Audiometry: Frequency 1	Experimental	19	-3.3	21.7	10.44	6.53
	Control	19	-1.7	18.3	5.70	5.95
Audiometry: Frequency 2	Experimental	19	-1.7	20.0	9.39	6.19
	Control	19	-5.0	20.0	5.45	7.00
Audiometry: Frequency 3	Experimental	19	5.0	52.5	19.61	11.34
	Control	19	3.3	20.0	7.18	3.90

Table 5
Experimental and control groups' audiometric results, right ear (in dB)

Test	Group	*N*	Min.	Max.	Mean	*SD*
Audiometry: Frequency 1	Experimental	19	-1.7	18.3	12.20	5.12
	Control	19	0.0	21.7	7.20	5.26
Audiometry: Frequency 2	Experimental	19	0.0	21.7	9.90	5.27
	Control	19	-5.0	18.3	5.80	5.51
Audiometry: Frequency 3	Experimental	19	7.5	42.5	19.70	9.01
	Control	19	2.5	22.5	10.40	4.88

Right ear. On the right ear audiometric tests we obtained the following differences of means between the experimental group and the control group: Frequency 1: 5.0 (SD = 6.89, $t(18) = 3.17$, $p = 0.01$), Frequency 2: 4.1 (SD = 6.37, $t(18) = 2.82$, $p = 0.01$), Frequency 3: 9.3 (SD = 10.83, $t(18) = 3.76$, $p = 0.00$).

ITPA subtests. On the ITPA subtests one point is given for each correct answer. The sum of these points makes up the raw score, which is converted to a scaled score on the basis of age-normed tables. Our results are reported as scaled scores in Tables 6 and 7.

Discussion

The pupils in the experimental group scored significantly lower than the pupils in the control group on all the audiometric tests, and the difference was greatest at the highest frequencies. As mentioned, it is common in audiometric screenings to use a score of 15 as the upper limit of the normal range. Using this score as our criterion, we see that all of the means were within the normal range, except for the experimental group's scores on the highest frequencies. The experimental group's scores for left/right ear were 19.6/19.7. One would have to call this a relatively modest loss of hearing. To the degree that this loss creates problems in the perception of speech-sounds, it would have to involve only those allophones whose identification depends crucially on those frequencies in particular. This is consistent with Tallal and her co-workers' findings (e.g., Tallal, 1980; Tallal & Piercy, 1974). They are of the opinion, however, that it is primarily the very brief transient sound changes that cause the problems.

Our findings permit us to conclude that pupils with phonological difficulties often have auditory abilities that function less well than pupils with normal phonological ability. Can we therefore claim that the auditory problems are the cause of their phonological problems? A certain minimum of hearing ability is of course necessary to perceive phonemes. The hearing loss in our experimental group, however, is so small that we doubt that it can create phonological problems of the type and degree we found. If there were a problem in perceiving some of the phonemes, we would expect the natural redundancy found in language and the context of the utterance to contribute to a filling in of the blanks. A person with a limited loss of hearing may, for example, have difficulty in discriminating between /s/ and /sh/ presented in isolation, but might nonetheless reliably grasp the difference between the words 'sea' and 'she' when they occur in natural speech.

If the limited hearing impairment we found in our experimental group is to explain the group's

Table 6
Experimental and control groups' results on the ITPA subtests

Test	Group	*N*	Min.	Max.	Mean	*SD*
ITPA: Auditory reception	Experimental	19	25.0	40.0	36.00	4.04
	Control	19	35.0	41.0	39.30	1.42
ITPA: Auditory association	Experimental	19	33.0	41.0	38.10	2.56
	Control	19	28.0	46.0	41.40	4.30
ITPA: Verbal expression	Experimental	19	28.0	45.0	33.80	4.76
	Control	19	30.0	51.0	41.80	5.70
ITPA: Grammatical closure	Experimental	19	22.0	42.0	35.84	5.43
	Control	19	34.0	47.0	42.95	3.99
ITPA: Auditorial sequential memory	Experimental	19	22.0	46.0	31.42	6.61
	Control	19	31.0	52.0	37.68	6.11
ITPA: Auditory closure	Experimental	19	25.0	38.0	32.37	3.89
	Control	19	32.0	43.0	38.21	2.59
ITPA: Sound blending	Experimental	19	25.0	38.0	31.42	4.30
	Control	19	36.0	38.0	37.26	0.81

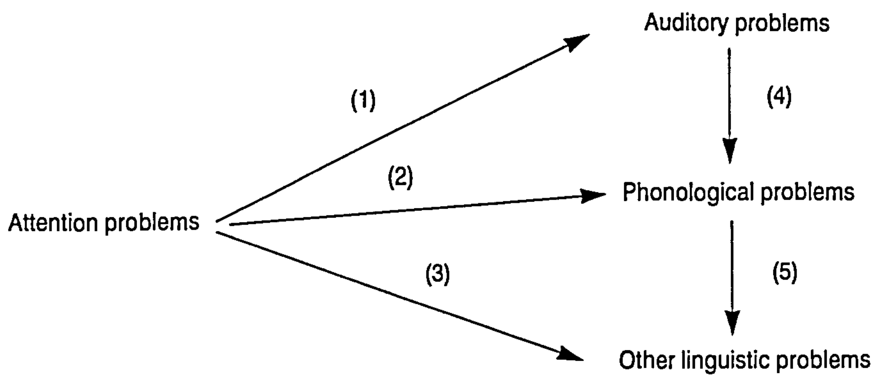
Table 7
Difference between experimental and control groups on the ITPA subtests

Test	Difference of means	*SD* of difference	Paired *t*-test	Sign.
ITPA: Auditory reception	-3.32	3.66	-3.96	0.00
ITPA: Auditory association	-3.32	4.30	-3.37	0.00
ITPA: Verbal expression	-8.00	6.81	-5.12	0.00
ITPA: Grammatical closure	-7.11	5.98	-5.18	0.00
ITPA: Auditorial sequential memory	-6.26	7.77	-3.51	0.00
ITPA: Auditory closure	-5.84	4.10	-6.21	0.00
ITPA: Sound blending	-5.84	4.07	-6.25	0.00

phonological difficulties, then the impairment would have had to be present in early childhood, when the child would naturally have learned to discriminate between similar phonemes. When the child, then, did not learn to discriminate some of the phonemes, then these phonemes would not have been entered into the long-term memory. Not having the identities of these phonemes the long-term memory would then make it very hard or impossible to learn the corresponding graphemes when the child was expected to learn to read and write.

But grapheme-phoneme problems like this would not seem to explain all the phonological difficulties we found prevalent in our experimental group. The nonwords our experimental group had problems with consisted for the most part of graphemes and phonemes which they otherwise had no problem in reading. An example in English would be the word "violin,"

Figure 1
Direct and indirect impact of the attention problems on hearing ability, phonological ability and general linguistic abilities.



which caused no problem, and the nonword "nilovi," which would be unreadable for them. Moreover, when we asked our participants to decide whether a nonword was a homophone to an "easy" real word or not, they scored very low —despite the fact that all the graphemes and phonemes in the test items were common in high frequency words with regular spellings.

We cannot rule out the notion that a hearing impairment in early childhood can lead to weakened phonological ability. In the studies of persons with great hearing impairments mentioned above, this is often the case. In our experimental group, however, persons with relatively great impairment in their phonological ability have a relatively modest auditory impairment. This encourages us to look for a third factor that can explain both the phonological and the modest auditory problems.

Is there a factor that can explain these cases of phonological problems, auditory deficits, and the type of language deficits we found on the ITPA subtests? Our assumption is that the pupils in the experimental group have problems in focusing their attention in a productive way. Hamlyn (1969) asked the question: "Is perception merely a matter of having the requisite sensory equipment? Surely there are numbers of things which we do not perceive, not because we have not the requisite sense organs, but because we are not paying attention, or for some similar reason" (p. 4)

We envisage that such attention problems (1) work directly on the auditory ability, which is then weakened, (2) they work directly on the phonological ability, which is also weakened, and (3) they also work directly on the other linguistic abilities, which are also weakened. In addition, we envisage (4) that the weakened auditory ability to a limited extent can have a negative impact on the phonological ability, and (5) that the weakened phonological ability to a somewhat greater extent can impact negatively on the other linguistic abilities (see Figure 1).

As a rule, the more a task deviates from well known and automatic tasks, the more difficult and necessary it is to use one's attention in a productive way. When the graphemes and phonemes in, for example, "violin" are presented as "nivoli," our experimental group had problems. It seems as if they are more dependent than the control group on automaticity. At the same time, it seems that they have a greater problem in *not* performing tasks automatically when automaticity is inappropriate (Toennessen, 1999).

The problem of knowing when to *not* perform a task automatically and when to apply one's attention in an unfamiliar yet productive way is also seen in connection with spoonerisms. Some tests call for the child to produce the spoonerism "Lohn Jennon" when given the stimulus "John Lennon." It can appear, then, that a lack of phonological awareness is only a part of a more general problem in being able to switch productively between two modes of problem solving, one involving a high degree of automaticity and the other based on awareness. "Switching" attention seems to be a factor in this group's problems. Hugdahl and Andersson (1987) maintain that "It may thus seem as if learning disabled children are more susceptible to attentional factors than normals, which may interact with language lateralization. This in turn may cause them to adopt a different information processing strategy when confronted with a written text" (p. 632). This conclusion seems to be supported by their own study of dichotic listening and reading aquisition in children (Hugdahl & Andersson, 1987).

Conclusion

Many studies indicate that hearing-impaired pupils have phonological problems that make it difficult for them to learn to read. At present there are few studies that make the opposite claim, that pupils with phonological problems also are hearing-impaired. Tallal and her co-workers seem to be making this claim. Their studies, however, are controversial on both theoretical and methodological grounds. Moreover, they have studied a broad and loosely defined group of "Language Learning Impaired Children," a group that includes both traditionally defined dyslexics and non-dyslexics.

In our study we have sought to restrict and clearly define our experimental group. We used only two phonological tests in our sampling and we included in the experimental group only those children with very poor scores. Our age and grade-level matched control group scored average or higher. We found significant differences between the groups in auditory and linguistic abilities.

We hypothesize that there is a common underlying cause which contributes to both the relatively minor auditory problems and the more serious problems in phonological and general linguistic processes. We believe that an important causal factor can be an unproductive use of attention. Even though this factor may prove to be important, we do not believe that it will account for all of the phonological problems. Furthermore, in order to find an effective treatment it will be necessary to determine the extent to which this psychological phenomenon is biologically rooted.

References

Bamford, J., & Saunders, E. (1991). *Hearing impairment, auditory perception and language disability* (2nd ed.). London: Whurr.

Burden, V., & Campbell, R. (1994). The development of word-coding skills in the born deaf: An experimental study of deaf school-leavers. *British Journal of Developmental Psychology, 12*, 331-349.

Dodd, B. (1980). The spelling abilities of profoundly prelingually deaf children. In U. Frith (Ed.), *Cognitive processes in spelling* (pp. 423-440). London: Academic.

Farmer, M. E., & Klein, R. M. (1995). The evidence for a temporal processing deficit linked to dyslexia: A review. *Psychonomic Bulletin & Review, 2*, 460-493.

Hamlyn, D. W. (1969). *The psychology of perception.* London: Routledge.

Hanson, V. L. (1989). Phonology and reading:

Evidence from profoundly deaf readers. In D. S. Shankweiler & I. Y. Liberman (Eds.), *Phonology and reading disability. Solving the reading puzzle* (pp. 69-89). Ann Arbor, MI: The University of Michigan Press.

Hoien, T., & Lundberg, I. (1991). *KOAS. Kartlegging av ordavkodings-strategiene* [KOAS. Mapping of word decoding strategies]. Stavanger, Norway: Center for Reading Research.

Hugdahl, K., & Andersson, B. (1987). Dichotic listening and reading acquisition in children: A one-year follow-up. *Journal of Clinical and Experimental Neuropsychology, 9*, 631-649.

Jensema, C. J. (1975). *The relationship between academic achievement and the demographic characteristics of hearing-impaired children and youth* (Series R, Number 2). Washington, DC: Gallaudet College Office of Demographic Studies.

King, C. M., & Quigley, S. P. (1985). *Reading and deafness*. London: Taylor and Francis.

Kirk, S. A., & Kirk, W. D. (1971). *Psycholinguistic learning disabilities. Diagnosis and remediation*. Urbana IL: University of Illinois Press.

Mann, V. A., & Liberman, A. M. (1983). Some differences between phonetic and auditory modes of perception. *Cognition, 14*, 211-235.

Mattingly, I. G., Liberman, A. M., Syrdal, A. K., & Halwes, T. (1971). Discrimination in speech and non-speech modes. *Cognitive Psychology, 2*, 419-430.

McCarthy, J. J., & Kirk, S. A. (1963). *The construction, standardization and statistical characteristics of the Illinois test of psycholinguistic abilities*. Urbana, IL: University of Illinois Press.

Nygaard, H. D. (1975). Den norske utgaven av Illinois Test of Psycholinguistic Abilities [Norwegian version of the Illinois Test of Psycholinguistic Abilities]. *Skolepsykologi, 1*, 3-11.

Strassman, B. K. (1992). Deaf adolescents' metacognitive knowledge about school-related reading. *American Annals of the Deaf, 137*, 326-330.

Studdert-Kennedy, M., & Mody, M. (1995). Auditory temporal perception deficits in the reading-impaired: A critical review of the evidence. *Psychonomic Bulletin & Review, 2*, 508-514.

Tallal, P. (1980). Auditory temporal perception, phonics and reading disabilities in children. *Brain & Language, 9*, 182-198.

Tallall, P. (1984). Temporal or phonetic processing deficit in dyslexia? That is the question. *Applied Psycholinguistics, 5*, 167-169.

Tallal, P. (1990). Fine-grained discrimination deficits in language-learning impaired children are specific neither to the auditory modality nor to the speech perception. *Journal of Speech and Hearing Research, 33*, 616-619.

Tallal, P., Miller, S. L., Bedi, G., Byma, G., Wang, X., Nagarajan, S. S., Schreiner, C., Jenkins, W. M., & Merzenich, M. M. (1996). Language comprehension in language-learning impaired children improved with acoustically modified speech. *Science, 271*, 81-84.

Tallal, P., & Piercy, M. (1974). Developmental aphasia: Rate of auditory processing and selective impairment of consonant perception. *Neuropsychologia, 12*, 83-93.

Toennessen, F. E. (1997). How can we best define 'dyslexia'? *Dyslexia, 3*, 78-92.

Toennessen, F. E. (1999). Awareness and automaticity in reading. In I. Lundberg, F. E. Toennessen, & I. Austad (Eds.), *Dyslexia: Advances in theory and practice* (pp. 91-100). Dordrecht, The Netherlands: Kluwer.

Toennessen, F. E. (1999). *Phonological and/or auditory deficits in dyslexia?* Manuscript submitted for publication.

Wrightstone, J. W., Aronow, M. S., & Moskowitz, S. (1963). Developing reading test norms for deaf children. *American Annals of the Deaf, 108*, 311-316.