

■ The Notion of ‘Phonology’ in Dyslexia Research: Cognitivism—and Beyond

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Phonology has been a central concept in the scientific study of dyslexia over the past decades. Despite its central position, however, it is a concept with no precise definition or status. The present article investigates the notion of ‘phonology’ in the tradition of cognitive psychology. An attempt is made to characterize the basic assumptions of the phonological approach to dyslexia and to evaluate these assumptions on the basis of commonly accepted standards of empirical science. First, the core assumptions of phonological awareness are outlined and discussed. Second, the position of Paula Tallal is presented and discussed in order to shed light on an attempt to stretch the cognitive-psychological notion of ‘phonology’ towards auditory and perceptual aspects. Both the core assumptions and Tallal’s position are rejected as unfortunate, albeit for different reasons. Third, the outcome of this discussion is a search for what is referred to as a ‘vulnerable theory’ within this field. The present article claims that phonological descriptions must be based on observable linguistic behaviour, so that hypotheses can be falsified by data. Consequently, definitions of ‘dyslexia’ must be based on symptoms; causal aspects should not be included. In fact, we claim that causal aspects, such as ‘phonological deficit’, both exclude other causal hypotheses and lead to circular reasoning. If we are to use terms such as ‘phonology’ and ‘phoneme’ in dyslexia research, we must have more precise operationalizations of them.

Keywords: phonology; connectionism; phonological deficit; circularity; definition; phonological awareness

INTRODUCTION

Until about the end of the 1960s, a common view of dyslexia was that it arose as a consequence of sensory or perceptual anomalies in the visual system. In the early 1970s, the focus moved to cognitive and linguistic factors—in particular, phonological factors. At about the same time, we also saw a rekindling of interest in biological factors, which had been a central concern at the very start of research on dyslexia (Miles & Miles, 1990). In recent years, Paula Tallal has brought the focus back to sensory and perceptual factors, but this time in the auditory system. Her work thus represents a break with tradition—but not a complete break, because she claims that phonological factors are still relevant (cf. Brady, Scarborough, & Shankweiler, 1996).

The present article consists of three major parts. First, we look into the phonological-deficit hypothesis in order to present and discuss the characteristics of the construction of phonology in this tradition. The second part examines the work of Paula Tallal, which constitutes a contemporary alternative to the predominant phonological-deficit hypothesis. In this second part, we wish to present and discuss the findings made, the theories used to explain the data and the various claims made by Tallal and her co-workers. The motivation for doing so is the search for conceptual clarity, because we claim that the notion of ‘phonology’ is highly unclear both in the original hypothesis and in Tallal’s version of it. The third part investigates the notion of ‘phonology’ beyond cognitivism. In this part, we do not give prominence to any one direction of phonology—several can in fact be considered useful. Instead, we focus on the basic prerequisites for such approaches to be empirically sound.

THE PHONOLOGICAL-DEFICIT HYPOTHESIS

The notion of ‘dyslexia’ has been defined in different ways over the past decades. However, notions like ‘phonology’, ‘awareness’ and ‘phoneme’ have been central in the dominating approaches to dyslexia. In short, it can be summarized that ‘phonology’ denotes the sound system, ‘phoneme’ denotes the basic unit in this system and ‘awareness’ is the means by which the individual can gain access to the sound system.

It should not be too controversial to claim that most dyslexia research in the past 30 years has built on a particular strand of linguistic theory. The linguists John C. Gumperz and Stephen C. Levinson describe how, in the 1960s, linguistics and psychology contributed to the rise of cognitive sciences ‘which favoured a strong emphasis on the commonality of human cognition and its basis on human genetic endowment’ (1996, p. 3). In cognitive sciences, the dominant linguistic strand has been generative grammar, a theory which gives priority to underlying linguistic structures through a distinction between *competence* (innate language faculty) and *performance* (speech). According to this distinction, competence carries the universal commonalities while performance is the more or less random realization of these structures in the particular language and situation (Chomsky, 1975). This distinction is also at the core of what is called autonomous linguistics:

Just as autonomous linguistics distinguishes between a speaker’s purely linguistic knowledge, determined by the language faculty, and his non-linguistic knowledge,

derived from pragmatic competence and the conceptual system, so autonomous phonology splits off the act of speech as an articulatory, acoustic, and perceptual event from the abstract linguistic system which is claimed to underlie the physical data. (Taylor, 1991, p. 28)

The belief in the existence of an underlying system along these lines is firm in dyslexia research: 'We earlier defined phonological coding as the ability to use speech codes to represent information in the form of words and parts of words.' (Vellutino, Fletcher, Snowling, & Scanlon, 2004). However, as we are not alone in thinking, this approach is unfortunate if the focus is to be kept on empirical science:

Faith is a beautiful thing, which a non-believer can only regard with awe. At the time of writing, that seems to be how matters stand. There are many who share Chomsky's faith, and for them 'The research program of modern linguistics' (Chomsky 1988: Ch. 2) must without arrogance be his program. Others cannot bring themselves to accept that it has empirical content. 'C'est magnifique, mais peut-être ce n'est pas la linguistique.' But all they can do is watch and wait. (Matthews, 1993, p. 252)

First, autonomous linguistics presupposes the existence of structures which are too abstract to be falsified by data—in other words, structures which cannot be treated as hypotheses (see discussion below). Second, the focus on underlying structures creates a huge amount of metaperspectives with a highly uncertain status. As an example, the linguistic descriptions of semantics, phonology, morphology and syntax are awarded the status of 'processes' in cognitive flow-charts (cf. Vellutino *et al.*, 2004, p. 4) without consideration of their function in linguistics. The fallacy of equating linguistic descriptions with mental processes was committed early on in Chomsky's authorship; to some extent already between *Syntactic Structures* (1957) and *Aspects* (1965). We consider this position to represent naïve realism.

Our conception of linguistic behavior is biased by a tendency to treat processes, activities and conditions on them in terms of object-like, static, autonomous and permanent structures, i.e., as if they shared such properties with written characters, words, texts, pictures and images. Though my discussion will be confined to linguistics, I am well aware that the same type of bias can be found in many other sciences. (Linell, 1982, p. 1)

As part of the turn towards linguistics and phonology in dyslexia research, scholars subscribing to the phonological-deficit hypothesis have adopted and reinforced central assumptions of orthodox generative grammar (see Table 1). This involves assuming the position of autonomous linguistics. However, this approach is problematic from an empirical point of view. Because of the distinction made between a stable and innate system (competence) and a variable, random use of this system (performance), every observable phenomenon is subordinated the abstract system by phonological rules. As a consequence, such rules obstruct the endeavour to meet high standards of empirical science. This is because priority is given to an abstract system with an axiomatic base, and the phonological rules formulate how the abstract system can account for variation in speech. In other words: it is hypothesized that there is a

Table 1. Overview of basic assumptions and common inferences underpinning the theory of ‘phonological awareness’

Phonology is linguistic, written language is not

Inferences

The lexicon can be accessed only by speech

Phonological structure is directly relevant to written language, but not *vice versa*

Phonology is natural, written language is an artifact

Inferences

Speech is a matter of ontogenesis, written language is simply an artifact

Speech is part of the human being, written language is external

Phonology means segmental, linear structure

Inferences

Prosody is peripheral, not part of phonological structure

Sound units are linearly ordered, discrete or not

Segmental structure is universal

Phonology is platonic

Inferences

Phonology is abstract, distant from the phonetic, acoustic pronunciation

Phonology must be accessed when learning to read

Phonology can be accessed only by awareness of phonological units

Phonology is highly representational

Inferences

There is a specific mental level where a phonological structure with psychological reality and communicative relevance can be identified and described

The representation is distant, and qualitatively different, from speech

deficit in the phonological system, but it is difficult to see how this hypothesis can be falsified. In this sense, a specific conception of phonology becomes an *a priori* entity which is left beyond discussion. This is remarkable considering the development of phonological theory in linguistic circles over the same period of time—a period characterized by major discoveries and advances (Horne, 2000).

The notions of ‘phonology’ and ‘awareness’

It can be argued that the turn towards phonology in dyslexia research was influenced by assumptions from the linguistic tradition in the joint venture of linguistics and cognitive psychology in the 1960s. In retrospect, it is evident that the turn towards ‘phonology’ was not accompanied by a thorough reflection of the adopted assumptions. There was simply no group of critical researchers focusing on the linguistic assumptions. Alvin Liberman is for many scholars an early linguistic *alibi* for reading and dyslexia research, however, his view of the relation between spoken and written language (Liberman *et al.*, 1989) reflects little more than traditional and questionable assumptions in the tradition of linguistics (Linell, 1982; Wengelin, 2002; Uppstad, 2005).

The lack of reflection on the notion of ‘phonology’ may turn out to have dire consequences, not least with regard to the extensive theory-building that has

been undertaken on the basis of the phonological-deficit hypothesis. What is more, there is a general vagueness in the research field concerning what 'phonology' means. Even the famous linguist Roman Jakobson refused to use the term 'phonology' back in the late 1970s, because of the conceptual mess (Jakobson, Taylor, & Waugh, 2002). And yet the confusion referred to by Jakobson is minor compared with the vagueness of the notion of 'phonology' identifiable over the past decades in the field of reading research. The Jakobsonian objection addresses the rejection by generative grammar of the structural view of distinctiveness, and therefore it amounts to precise criticism of a competing theory. In reading research, the maintenance of the notion is inconsistent, denoting partly letter sounds, the sound system, sounds in general, a language module in the brain, as well as mental units of sound. The outcome of this inconsistency is that the notion of 'phonology' has been fully encompassed by the notion of *phonological awareness*. This claim can be made on the basis of the following assumptions:

- (1) *Phonological structure is what is accessible by awareness*: Because phonology is abstract, it is different and distant from the acoustic signal and the acoustic shape of speech. Phonological structure can therefore be accessed only by awareness of units. According to this assumption, speech must be *phonetic* in general but the units which one can be aware of (phonemes) are *phonological*.
- (2) *The distinction between the notions of 'phonological' and 'phonetic' is not operationalized*: The problem is that 'phonological awareness' is an extremely vague concept and is therefore of little use in the maintenance of the phonetics-phonology distinction.
- (3) *Awareness is a necessary and sufficient condition for category membership*: This means that there are no categories other than those we can be aware of. The phonological-deficit hypothesis focuses on awareness of segments, and uses this awareness to represent phonological skills. There is no tradition in the research field of dyslexia for extensive, phonological analysis of words and utterances. Phonological rules are relevant only to a certain extent, and they are used mainly to describe aspects of awareness. According to this assumption, awareness is a necessary and sufficient condition for the evaluation of phonological skills. A second problem related to this assumption is the belief that awareness can be measured independently from other skills.

The arguments concerning 'phonological' and 'phonetic' may seem like hair-splitting to some scholars. In our view, however, they are of great importance, mainly because the basic assumptions about phonology inherent in the phonological-deficit hypothesis *require* that a distinction be made between the two terms. This is because the basic theory underpinning the phonological-deficit hypothesis is based on autonomous linguistics, and the hypothesis presupposes two distinct levels of explanation: a phonological one and a phonetic one (speech). In the research tradition focusing on 'phonological awareness', it is hardly ever shown how to move between these two levels of description by phonological rules which are teleological and normative. What is more, few can perform such analyses in any consistent way, and even fewer have seen any reason to do so. This is alarming, because the use of phonological rules is the only

way to show the connection between the two levels in autonomous linguistics. To put it short: autonomous linguistics in general can be questioned from an empirical perspective, but autonomous phonology without phonological rules is nothing less than a disaster. However, in some of the directions taken by generative phonology in the last decade, there is also a blurring of the distinction as to what is 'phonological' and 'phonetic', respectively (Kager, 1999), but here the blurring is intentional and founded on basic assumptions about acquisition. In the phonological-deficit hypothesis, though, the blurring is accidental and projects a flaw in the conceptual system.

If we take a look at Vellutino's work from 1979, we find that his intentions are ambitious:

The primary purpose is to examine the theoretical foundations of these conceptualizations, closely scrutinizing their logical consistency, their empirical validity, their overall productivity. A special effort is made to discuss the methodology and conclusions drawn from the studies reviewed, as well as to analyze their conceptual bases. (Vellutino, 1979, p. 3)

Considering the fact that this book introduces the 'linguistic turn' in dyslexia research, it is highly remarkable that none of the intentions quoted above aims at the core concepts of the new paradigm—the notions of 'linguistic' and 'phonology'. That is why we will make an effort in this part of the article to outline how the notions of 'phonology' and 'linguistic' are established in the writings of some central proponents of the phonological-deficit hypothesis. The purpose of doing so is primarily to include the notion of 'phonology' in the hypothetical construct of the phonological-deficit hypothesis.

The foundation of the phonological-deficit hypothesis

The notion of 'phonology' in dyslexia research is linked to a specific conception of 'linguistic'. Since the phonological-deficit hypothesis is an explanation of how the acquisition of written language is hampered by a deficit in the ability for spoken language, the notion of 'linguistic' is restricted to spoken language. Written language is only 'linguistic' in the sense that it is dependent on spoken language skills. (Lieberman *et al.*, 1989; Vellutino, 1979; Vellutino *et al.*, 2004). Throughout Vellutino's book on dyslexia (1979), the notion of 'linguistic' is reserved for speech. Explicitly, the same position is held in the 2004 article of Vellutino *et al.*:

Visual coding processes, broadly defined, refer to sensory and higher-level visualization processes that facilitate storage of representations defining the visual attributes of environmental stimuli, including the graphic symbols used to represent written words. Linguistic coding processes refer to processes that facilitate language acquisition and the use of language for coding, storing and retrieving information. (Vellutino *et al.*, 2004, p. 4)

The distinction between 'visual' and 'linguistic' may well be because the linguistic turn was an antithesis to earlier hypotheses implying visual deficits. As a consequence, the notion of 'linguistic' denotes speech, and written language is simply considered as a representation of speech. Paradoxically, in this way written language—being parasitic—can be 'phonological', but not 'linguistic' by

the fact that 'phonology' seems to denote a structure of spoken language relevant to written language while 'linguistic' denotes language ability in spoken language: 'Written words are encoded (symbolized) representations of spoken words, and spoken words are encoded representations of environmental experiences and entities.' (Vellutino *et al.*, 2004, p. 3).

In our view, it is clear that the core assumptions of orthodox generative phonology (Chomsky & Halle, 1968) are adopted by proponents of the phonological-deficit hypothesis, (Churchland, 1986; Gardner, 1985) and that these assumptions are maintained in an unfortunate way (see Table 1). In his article (Öhman, 1979) in a *Festschrift* dedicated to the engineer and phonetician Gunnar Fant, the phonetician Sven Öhman takes Fant's contributions to linguistics as his starting-point in discussing mainly how speech technology enables the researcher to advance beyond subjective introspection. According to Öhman's view, the study of speech has historically been restricted by the lack of technology for studying the acoustic signal. Therefore, the traditional analysis of speech 'was derived from a subjective, introspective analysis of what one does in producing the sounds of an utterance' (p. xvii). According to him, it is therefore necessary to confront what we 'know' (from subjective introspection) about speech with what the study of the acoustic signal may tell us:

The point is rather that there is a stage in the theoretical analysis of the linguistic structure of the acoustic speech signal, beyond which unaided auditory perception is incapable of taking us. And it is beyond this stage that we need to reach in order to be able to assess the soundness of some of our most deeply seated theoretical principles. (Öhman, 1979, p. xviii)

Moreover, such a study is necessary in order to reflect on where the conception of sound structure comes from. Among what Öhman calls 'our most deeply seated theoretical principles' he highlights three traditional conceptions of sound structure to be challenged by modern speech technology:

- (1) The *discreteness principle* says that an utterance of spoken language is always made up of linguistically-*indivisible* building blocks drawn from a fixed and finite inventory of types of such blocks [>the compositional view of language].
- (2) The *linearity principle* dictates that these building blocks be always arranged in a linear series along the time axis.
- (3) The *principle of articulatory posturality* claims that the building blocks of an utterance are best understood as certain postures of the organs of speech. (Öhman, 1979, p. xviii, italics mine)

The major discoveries made in phonology over the past three decades have led to the above principles all being rejected as unfortunate (cf. Horne, 2000). The advances made in the field of prosody has shown that sound structure can be better described as acoustic features on different tiers that are associated with a segmental tier in a dynamic way (rejection of principle 1 above). The same discoveries in prosody has shown that the arrangement of features is more nuanced than the above mentioned principle 2, and modern phonology is therefore often referred to as *non-linear phonology*. The same discoveries highlight the importance of the characteristics of the dynamic acoustic signal,

while aspects of articulation are not focused in phonological description (principle 3).

This focus on prosodic research is partly due to the fact that developments in speech technology have made it possible to examine the acoustic parameters associated with prosodic phenomena (in particular fundamental frequency and duration) to an extent which has not been possible in other domains of speech research. It is also due to the fact that significant theoretical advances in linguistics and phonetics have been made during this time which have made it possible to obtain a better understanding of how prosodic parameters function in expressing different kinds of meaning in the languages of the world. (Horne, 2000, p. 1)

Notwithstanding this, the scientific study of dyslexia has maintained the principles referred to by Öhman in a quite dogmatic way. This situation means that the theoretical principles underpinning the phonological-deficit hypothesis seem highly questionable. In order to make empirical progress, the proponents of phonological awareness must with precision elaborate what is denoted by the concepts of both 'phonology' and 'linguistic'.

Implications for application

From the theoretical principles mentioned in the previous paragraph as underpinning the phonological-deficit hypothesis, some features of application can be outlined. Every generalization of this kind will be controversial, because the theorists involved certainly do add important reservations and nuances. Nevertheless, the generalization presented below is probably representative of the 'period of normal science' for this paradigm (Kuhn, 1970).

The main problem in dyslexia research is that the phonological theory has not been maintained in a way enabling the basic assumptions to be continuously exposed to falsification. A second set of problems, which can be derived from the first, originate from an unreflected conceptual system. In the situation obtaining, the label 'phonology' may be applied to anything related to sound in connection with speech and writing; whether a given sound is phonetic or phonological may be left to the author's ability and desire to remain consistent throughout a paper, and the outcome of this is that the notion of 'phoneme' is the closest one gets to make explicit what is meant by 'phonology'.

Problem: the main argument in phonological awareness can be described as circular

The main argument for the theory of phonological awareness is the high correlation between awareness of sound segments and reading performance (Vellutino *et al.*, 2004). This finding has been replicated so often that it is considered to reflect a causal relationship. However, two conditions have to be met for this to be the case, namely: (1) that the structure of speech is strictly segmental (from an ontological perspective); and (2) that writing is parasitic on speech, i.e. that written language is considered as simply a representation of spoken language. The latter condition rests on the idea that 'Written words are encoded (symbolized) representations of spoken words' (Vellutino *et al.*, 2004, p. 3). Both conditions can be considered to be assumed in the so-called

alphabetical principle. In fact, (1) has been strongly questioned in phonological theory (Horne, 2000) and (2)—the relation of spoken and written language—has never been treated as a true hypothesis. In every other respect, the relationship between awareness and reading performance has strong implications not of causality but of circularity: it would seem to amount to saying ‘those who succeeded, succeeded’ and ‘those who did not succeed, did not succeed’. In other words, there is shown to be a high correlation between the level of the same property in the same individual at two points in time, regardless of whether the studies involved are experimental or interventional. What tends to happen is that ‘phonological tests’ are conducted on pre-school children. Later on, when the same children have entered school, they are given reading tasks which focus primarily on the ‘phonological part’ of reading. No wonder that the correlation is high! For the purpose of illustration, a corresponding situation could be imagined if we, say, assessed IQ in pre-school children and then compared the results obtained with results obtained from the same children after they had entered school. The obvious origin of the circularity is the segmental analysis of speech, which fits in with the segmental structure of writing. With regard to the first point above, relating to the segmental structure of speech, modern phonology has shown how phonological structure does not favour the segmental tier (Horne, 2000). With regard to the second point, relating to writing as parasitic on speech, we should treat the relationship between spoken and written language as a hypothesis in order to search for true empirical findings.

Surprisingly, the possibility of circularity is hardly ever discussed inside the paradigm, even if there are strong potentials in such a direction. Goswami and Bryant’s (1990) questioning of the phonemic focus is a relativization of the phonemic structure, but this insight is simply added to and rendered harmless in the paradigm’s phonological theory. Ehri’s (1997) position of written language as linguistic also strongly challenges the main argument of the current theory. Nevertheless, it is enclosed in the theory as an alternative to Liberman’s view, and no mention is made of its potential for falsification of the mainstream theory.

One may ask how such patience with findings contradicting a theory can be possible in an empirical science. A plausible answer is that this ‘patience’ is due to overly vague definitions. Let us take an example from geometry: If we want to generalize the concept of a circle, we have to set some features of some circles aside. If we investigate circles of different diameters, we will discover that, independently of the length of the diameter, the circumference will be 3.14 times longer. The more general term ‘circle’ does not have a fixed circumference or diameter, and we therefore disregard these features. This notion of ‘circle’ is therefore more abstract than the notion of ‘a circle whose circumference is 10 cm’. However, if we generalize further from the notion of ‘circle’ to the notion of ‘figure’, we obtain a term which is less useful in science. This is because, in the notion of ‘figure’, we set aside so many features that defining the notion becomes difficult. As a consequence, the notion of ‘figure’ lacks precision compared with ‘circle’, and will also be less fruitful as a scientific notion. Analogously, autonomous linguistics gives priority to an abstract construction which is not directly accessible by empirical data, resulting in a situation where the abstract construction is confused with the features observed.

If we take a look at the state of the art in dyslexia research, we find that Vellutino *et al.* (2004) highlight the causal relationship between phonological

awareness and the ability to read and write. Their notion of causality is, however, constrained by what we have claimed to be poor definitions of basic terms. If the notion of 'phonology' lacks precision, then the argument for causality is flawed.

This is to say that, viewed from a different theoretical position, the main argument used in theories of phonological awareness can be described as circular. It is therefore, in light of the philosophy of science, high time to shout 'the Emperor has no clothes!'. While such a shout does not amount to a conclusion, it does at least provide a new perspective which may underline the hypothetical character of every paradigm's phonological theory. Another related problem is the lack of distance to their own theoretical foundation which can be identified in, for example, Vellutino *et al.* (2004). The notion of 'logic' in the following quotation in fact refers only to the borders of their own theory: 'Etiological theories, which implicate deficits in such abilities as causally related to reading difficulties, can be ruled out on logical grounds alone and they have not fared well in empirical research.' (Vellutino *et al.*, 2004). And if we go on to compare the lack of precision of the concepts of 'phonology' and 'linguistic' with Vellutino *et al.*'s objection to the dual-route model, we see a clear mismatch of ideal and practice: 'Although such findings are suggestive, the double deficit hypothesis can be challenged on theoretical, interpretive, and methodological grounds. As regards its theoretical underpinnings, we suggest that the 'precise timing mechanism' that presumably underlies the formation of orthographic codes lacks the type of specification that would lend it psychological reality and allow it to be evaluated experimentally as a valid hypothetical construct.' (Vellutino *et al.*, 2004, p. 14).

A spectre is haunting reading research, and especially the field of dyslexia—the spectre of the phoneme. Interestingly, most theorists reject this spectral notion in some ways. With reference to experimental research, Vellutino claims that the phoneme is not the unit used in speech processing (Vellutino, 1979). A.M. Liberman first claimed the phoneme as the unit in speech. Later on, he has repented and admitted that there is no discrete, observable phoneme; instead, it can be found deep in the phonetic module in the shape of phonetic gestures (Liberman, 1997). Goswami and Bryant reject the phoneme as the only structure one can be aware of. Nevertheless, the phoneme is still there. And the problem is that, in the maintenance of the theory of the phoneme, no alternatives to the basic theory have been thoroughly discussed; instead, they are dogmatically rejected (see for example Liberman's rejection of Tallal and Lindblom (Liberman, 1999)). As a consequence, we have a situation where the phoneme is both rejected and accepted, which naturally only enhances the confusions. The inductive character of theory-building is especially clearly seen in the writings of Alvin and Isabel Liberman, (Liberman, 1997, 1999; Liberman *et al.*, 1989), where dogmatic arguments are deployed against features of theoretical positions which are not at all compatible with the authors' own position. While this kind of controversy is of course not unusual in science, the proportion of arguments belonging to the dogmatic category is alarming. These arguments are clearly not sufficient to prove A.M. Liberman's claim about the relationship between spoken and written language. In our view, dogmatic positions should be avoided in order to maintain high standards of empirical science. This can be done by studying behaviour in written and spoken language, without *a priori* assumptions of causal relationships.

THE AUDITIVE-DEFICIT HYPOTHESIS

The position of Tallal and her co-workers is interesting because it partly represents a break with the tradition presented above, and because it places the focus on perception as a source of deficit. (Even though Tallal's work was pointing in this new direction already in the 1970s, it is only in recent years that more considerable attention has been paid to it.) In this respect, the work of Tallal stands as an alternative to the mainstream phonological focus. Tallal *et al.* (1996) claim that her earlier work on 'language-learning-impaired (LLI) children' has shown that: '[R]ather than deriving from a primarily linguistic or cognitive impairment, the phonological and language difficulties of LLI children may result from a more basic deficit in processing rapidly changing sensory inputs.' (p. 81). One of the reasons why this research has received a great deal of attention in recent years is that CD-ROM programs have been developed which are said to be very effective in treating language difficulties in general and dyslexia in particular: 'In the present study we have demonstrated that training children with speech stimuli in which the brief, rapidly changing components have been temporally prolonged and emphasized, coupled with adaptive training exercises designed to sharpen temporal processing abilities [...] results in a dramatic improvement in receptive speech and language in LLI children.' (Tallal *et al.*, 1996, p. 83).

In this part of the article, we wish to present and discuss the findings and theories which have been used to explain the data and the various claims made by Tallal and her co-workers. This will be done as an alternative to mainstream thinking, but also to proceed towards conceptual clarity, which we claim cannot be obtained unless one goes beyond the positions evaluated in the present article.

The notion of 'dyslexia' in the auditive-deficit hypothesis.

Miller and Tallal (1996) have not studied dyslexics *per se*, but rather the broader group of what they term 'language-learning-impaired (LLI) children'. This group is rather unclearly delimited, as can be seen from this partial definition: 'We use the term Specific Language Impairments to refer to a type of communication disorder similar to the Diagnostic and Statistical Manual of Mental Disorders—Fourth Edition (DSM-IV, 1994).' (note on p. 9). Even though Miller & Tallal (1996, p. 9) remind us that 'phonology is one of five basic components of oral language (phonology, semantics, morphology, syntax, pragmatics)', it would seem to be the case that they consider phonology to be the *most important* factor of language. In particular, it seems as if they are claiming that explaining phonological problems is much the same thing as explaining most cases of LLI: 'Taken together, these experimental findings led us to hypothesize that the deficits underlying the phonetic reception limitations of a LLI child might arise in early life as a consequence of abnormal perceptual learning that then contributes to abnormal language learning.' (Merzenich *et al.*, 1996, p. 77). Dyslexics, then, seem to be a major subgroup of LLI children. The imprecise delimitation of the dyslexia group makes it difficult to draw any conclusions regarding samples based on more specific definitions of 'dyslexia' (cf. Tønnessen, 1995, 1997; cf. also Bishop & Snowling, 2004).

Symptoms

During the last two or three decades, Tallal and her co-workers have claimed that the phonological deficit found in dyslexics and dysphasics can be explained as a result of auditive anomalies (Tallal & Piercy, 1973, 1974; Tallal *et al.*, 1996). For example, Tallal (1984) claims that the phonological deficit is a symptom of an underlying deficit in auditory temporal processing. Tallal, Miller, and Fitch (1993) present three interlocking claims: (1) rapid auditory temporal processing is a decisive factor in speech perception; (2) the specialization of the left hemisphere for speech perception (and phonology) found in the vast majority of right-handed people has to do with this hemisphere's specialized ability to perform rapid auditory temporal processing; and (3) the phonological deficit typically found in, among others, dyslexics is due to a deficit in rapid auditory temporal processing.

Moreover, they make the further claim that 'LLI children commonly cannot identify fast elements embedded in ongoing speech that have durations in the range of a few tens of milliseconds, a critical time frame over which many phonetic contrasts are signalled [...] For example, LLI children have particular difficulty in discriminating between many speech syllables, such as [ba] and [da], which are characterized by very rapid frequency changes (formant transitions) that occur during the initial few tens of milliseconds.' (Tallal *et al.*, 1996, p. 81). These children's problems in identifying phonetic details and nuances in speech are said to have many negative consequences: '[T]his basic temporal processing deficit may disrupt the normal sharpening of neurally represented phonetic prototypes for the native language in LLI children, resulting in a cascade of negative effects on subsequent receptive and expressive language development—and ultimately resulting in a failure to generate the robust phonetic code that is so essential to learning to read.' (Tallal *et al.*, 1996, p. 82).

This means, first of all, that we should be finding that dyslexics exhibit a reduced ability to understand speech. There are indeed some findings that would seem to indicate that this is the case, in particular with regard to the youngest dyslexics. On the other hand, it is often claimed that a characteristic trait of dyslexics is the discrepancy between their fairly normal ability to understand speech and their defective understanding of written material (Aaron, 1989; Stanovich & Siegel, 1994; Lyon, 1994).

Another consequence of Tallal's theory would seem to be that dyslexics should exhibit many errors in articulation, and that they should be using words such as 'hat' and 'cat' incorrectly or inconsistently, because they cannot correctly identify and discriminate between the initial phonemes /h/ and /k/. Now, we do find symptoms like these in some dyslexics, but rarely to any great degree (Scarborough, 1990).

Tallal *et al.* (1996) are of the opinion that the 'temporal-processing deficit' hinders 'the normal sharpening of neurally represented phonetic prototypes', thereby leading to a 'failure to generate the robust phonetic code'. As far as we can see, this should primarily be causing problems in the young pupil's grasp of the grapheme-phoneme correspondences. If some of the phonemes found in the pupil's long-term memory are not correct, this will lead to problems in learning to read and write *all* words containing these phonemes. The child should then have equally great problems with these phonemes in frequently occurring words and in non-words; what should be decisive is whether or not a word contains the

poorly learned phoneme. This, however, seems to contradict findings which show that most dyslexics have most difficulty reading unfamiliar words, pseudo-words and, especially, non-words (cf. Rack, Snowling, & Olson, 1992).

What exactly do Tallal and her co-workers mean when they state that the LLI child's phonetic codes are unclear and unstable? Cognitive psychology holds that the phonemes are stored as mental representations. It is not immediately apparent how a mental representation can be unclear or unstable. Anything represented in long-term memory has to be something definite. (Of course it can always be wrong, but wrong representations are neither unclear nor unstable—they are merely wrong.)

Does this mean that we are unable to account for 'unclear' or 'unstable' representations within the framework of cognitive psychology? We think not. The best way of doing so, we think, is to be clear about the difference between an ability and the exercising of that ability. In other words, we may conceive of the representations in long-term memory as being constant, while the performance based on those representations is variable. The vagaries of the particular situation may well impact negatively on a person's performance, but it is difficult to see how a permanent deficit in the temporal and/or auditory systems could sometimes have an impact and sometimes not.

When Tallal describes the psychological mechanisms underlying dyslexia, she often expresses herself, in our view, unclearly and incompletely. Nonetheless, our impression is that her thinking is fairly solidly planted in cognitivism's mentalistic or symbolic paradigm. Her 'unclear' or 'unstable' mental representations in long-term memory would actually be easier to account for within the conceptual framework of, for example, connectionism. Connectionism is based on the idea that the activation in a unit and the weights between units are continuous rather than binary (0 or 1). This allows connectionism to explain all degrees of unclarity and instability (cf. Bechtel & Abrahamsen, 1991). In our view cognitive approaches are still predominant in dyslexia research. We consider connectionism to be a combination of behaviouristic and cognitive approaches (Tønnessen, 1999b). In our view Snowling and Hulme are interesting exceptions (e.g. Hulme, Quinlan, Bolt, and Snowling, 1995; Snowling and Hulme, 1999). However, we do not consider that they have used all the potentialities in connectionism.

This having been said, we can return to the question of why unclear or unstable representations should arise as a consequence of a child not hearing certain sounds. The sounds that the child does hear, or perceive, are clear and stable; so why should the sounds that he or she does not hear or perceive suddenly be unclear or unstable?

Regardless of whether we work in a cognitive or a connectionist framework, it is difficult to see how small details and nuances in perception can have such a decisive impact on language learning as Tallal is claiming. Both cognitivism and connectionism, and other schools as well, stress the role of context in both perception and learning. It is a generally accepted fact that we usually try to fit information together into coherent wholes. Here is an example. Let us say that someone has difficulty in discriminating between the phonemes /h/ and /k/ when they appear in isolation. That person would most likely have no trouble keeping things straight when presented with the sentences: 'Take off your hat' and 'Let out the cat'. Now, would Tallal claim that our subject in both cases

actually 'heard' the word 'cat'—or the word 'hat'? Or does our subject hear only /æ t/? When we take into consideration the great amount of redundancy found in language, it certainly seems quite probable that the /k/-/h/ distinction problem would resolve itself over time. After all, a person initially handicapped by not being able to perceive this distinction would be corrected many times in his or her early years and thus make the necessary adjustments to perception in light of the context.

Perhaps the most important objections to Tallal's auditive work have come from Isabelle and Alvin Liberman and those working in their tradition. (Shankweiler & Studdert-Kennedy, 1967; Mattingly & Liberman, 1990; Mody, Studdert-Kennedy & Brady, 1997). The question they have raised may be formulated like this: By placing so much emphasis on auditive details and fine discrimination, has Tallal misrepresented the nature of language? Studdert-Kennedy & Mody (1995) comment thus: 'First, a CV formant transition is not a 'series of rapidly changing acoustic events,' but an integral spectral sweep reflecting the continuously changing resonances of the vocal tract, as a speaker moves from a point of closure into the following vowel. Second, as many experiments have shown (e.g. Mann & Liberman, 1983; Mattingly, Liberman, Syrdal, & Halwes, 1971), a brief formant transition removed from the speech signal is heard as a rapid, integral glissando, or 'chirp,' of which the parts or 'spectral changes' cannot be perceptually individuated.' (p. 511).

Mann and Liberman (1983) make this claim: 'Given transitions that change in relatively small physical steps, from one appropriate for /d/ to one appropriate for /g/, the percept changes, not in correspondingly small steps, but suddenly (Mattingly *et al.*, 1971; Studdert-Kennedy & Shankweiler, 1970). This nearly categorical shift marks a sharp boundary between the phones [d] and [g]; it is commonly reflected and measured as a relative increase in discriminability of the stimuli at the category boundary.' (p. 212). In our view, we have enough evidence to claim that language is categorical in some sense of the word. But we must take care not to conceive of the boundaries between the phonemes as clear-cut and absolute. We cannot define phonemes by a set of necessary and sufficient conditions. Instead, the similarities among the sounds categorized as a certain phoneme are rather like the similarities one finds among members of a family. Rosch (1973) measured the reaction time that it took subjects to classify various instances under concepts. The finding made was that the degree of typicality predicted the speed at which an instance would be classified. Thus a robin, which rated as a highly typical bird, was quickly classified as a bird, while a goose, which was not thought to be a very typical bird, was classified more slowly. Magnetic attraction is another image used in phonetics to explain how sounds are categorized into phonemes: the farther away something is from the centre of the magnetic field, the weaker is the influence of the magnet (see e.g. Kuhl, 1991). For a discussion of the status of the concept of 'phoneme', see Uppstad & Tønnessen (2005).

Explanations

Miller and Tallal (1996) make this claim: '[W]e believe that we have identified an underlying neurological impairment that disrupts temporal processing rates in the brains of language learning impaired individuals' (p. 8). Taken together with

the suggestion that the problems dyslexics have can be traced back to anomalies in the magnocellular system (Livingstone, Rosen, Drislane & Galaburda, 1991; Galaburda, Menard, & Rosen, 1994; Miller, & Tallal, 1996; Fitch, Tallal, Brown, Galaburda, & Rosen, 1994), we discern the following implicit chain of causes in Tallal's and her colleagues' reasoning: (1) Neurological impairment leading to (2) anomalies in temporal processing leading to (3) auditory anomalies leading to (4) phonological anomalies leading to (5) language and cognitive problems. As we see their work, only the first link in this chain, the neurological impairment, is purely biological. All of the subsequent links belong to the domain of psychology. Even though Tallal and her colleagues often give the impression that the causal chain starts off with biological factors, we nonetheless see some statements that point in the opposite direction. For example, Merzenich *et al.* (1996) write: 'These studies also strongly indicate to us that there may be no fundamental defect in the learning machinery in most of these children.' (p. 80).

If Tallal and her colleagues are claiming that dyslexics' root problem is a learning problem, then it is difficult to see which type of theory of language learning they are basing their assumption on. Theories of language learning would seem to fall into various types. According to Aslin and Pisoni (1980), there are four types of theories about the child's perceptual development: (1) The *universal theory* claims that children are born with the ability to identify and discriminate all sounds in all languages. In the course of the child's first years of life, this 'universal' ability shrinks, as the phonemes not regularly encountered by the child are not reinforced. Thus an inborn wealth of nuances and distinctions is gradually reduced. (2) The *attunement theory* posits a development which goes in the other direction: here, the child starts out with only a few rough categories, which over time become finer and finer as a result of stimulation. (3) The *perceptual-learning theory* assumes that we are not born with any categories at all; everything has to be learned. And finally, (4) the *maturational theory* says that the ability to phonologically identify and discriminate between phonemes unfolds according to a genetically determined time-table, irrespective of early experience. Tallal's thinking seems to be most in accordance with theory types (2) and (3).

Auditive and temporal factors in dyslexia

Auditive factors

A.M. Liberman and his followers focus on what they see as Tallal's disregard for the categorical nature of language. To the extent that one explains phonology on the basis of non-categorized sound waves, one explains something linguistic on the basis of something non-linguistic. This may be considered a form of reductionism (see, e.g. Garfinkel, 1991; Tooley, 1993).

We see a close analogy in the phenomenon of colour. If we try to define colours on the basis of light-wave length, we run into the same problem. While there is indeed a perfect correlation between wavelength and colour, what we have is not a causal relationship. Rather, the relationship between wavelength and perceived colour is better described by an image of a mountain top. The mountain has two or more sides with different appearances. Neither side is the 'cause' of the other(s), even though they are of course closely related.

If the theory of Tallal and her co-workers seems reductive, their practice seems to be the opposite. The training program devised by Tallal and her colleagues

makes one wonder whether they are trying to create something linguistic with the help of something non-linguistic. Is this possible? Well, first we have to remember that sound waves are a necessary, but not a sufficient, condition for perceiving phonemes. In this sense, we see that auditory factors are relevant to phonology. On purely theoretical grounds, we cannot rule out the possibility that auditory training can help phonological development. Whether or not this is actually the case is a question that will have to be decided empirically. And it is also an empirical question to try to determine how detailed the auditory information given to the child should be.

THE NOTION OF 'PHONOLOGY' BEYOND COGNITIVISM—THE NEED FOR A VULNERABLE THEORY

The problem with A.M. Liberman's 'right' theory is its platonic character, where every important phonological feature is beyond falsification. This way of thinking is very much like Chomsky's (see Table 1). What is more, awareness is used for capturing the units of phonology, without any critical discussion of how awareness can be defined and operationalized.

In research on dyslexia, we should pick the theory which has the best descriptive and explanatory potential, and which is the most vulnerable, i.e. which is easiest to falsify. 'Vulnerability' is chosen as a criterion here because it refers not only to the binary logical property of 'falsifiability'—i.e. whether a hypothesis can or cannot be falsified. Rather, this notion focuses on the ease with which a hypothesis can be falsified, and it is therefore a practical criterion as regards the search for scientific truth. Our notion of 'vulnerability' as a practical criterion is in line with Karl Popper's philosophy of science (Popper, 1965; Popper & Eccles, 1977). Indeed, Tallal's theory is highly vulnerable, and therefore it can be thoroughly discussed and perhaps falsified. In this respect, Tallal's theory is more valuable than e.g. Liberman's position.

In mainstream dyslexia research, phonological representations play a central role (Uppstad, 2006a; Uppstad & Tønnessen, 2005). We claim that a strong focus on representations constitutes a major obstacle to a revitalized conception of the notion of 'phonology' beyond phonological awareness. This is because the idea of representations presupposes introspection, which cannot be falsified. If we consider the enterprise of science to be about description, explanation and understanding, the notion of 'phonology' must also be located with reference to these different purposes. Representations serve the purpose of description and understanding. In linguistics, one rarely leaves the domain of description, and this purpose is also predominant in the linguistic theory that constitutes the foundation of cognitive sciences. This fact represents a problem when causal hypotheses such as the phonological-deficit hypothesis are presented: it is not possible to state any falsifiable hypotheses concerning causality. Scientific disciplines searching for explanations have to be highly sensitive to the quality of their conceptual apparatus. If we want to explain, we need a conception of how descriptions and explanations relate. In our view, the purpose of explanation places specific demands on how we elaborate and maintain descriptions. As we see it, the most fruitful position is to consider descriptions as hypotheses (Tønnessen, 1997). The overall problem with scientific disciplines focusing on

description is that they produce static perspectives. This is the case with both traditional linguistics and cognitive psychology. In our view, the connectionist position seems to represent the best potential for escaping from cognitive science and its representational, descriptive focus (cf. Bechtel & Abrahamsen, 1991). Phonology is primarily descriptive, but in reading research it is—without further reasoning—widely applied as explanation. Nicolson (2002) points to this problem for proponents of the phonological-deficit hypothesis. The same problem is associated with the status of the concept of ‘phoneme’ (Uppstad & Tønnessen, 2005).

A vulnerable theory also requires precise definitions of core concepts. A more precise statement is easier to falsify than a vaguer one. In this sense, the notion of ‘phonological awareness’ faces an uncertain future. So far we have focused on the notion of ‘phonology’, but the other part of the phrase, ‘awareness’, probably needs as much rethinking as the first. Important questions in this context are: (1) Are the important aspects of sound seized through awareness? and (2) Is awareness isolated from other skills? In our view, the lack of adequate answers to such questions highlights the vague conceptual apparatus found in the theory of phonological awareness. Concerning the first question, Goswami & Bryant (1990) present interesting positions which relativize the phonemic focus. Still, this is a potential that cannot be fully exploited in the framework of phonological awareness and cognitivism. Concerning the second question, Tønnessen (1999a) claims that awareness cannot be separated from automaticity. This position involves a relativization of awareness, in suggesting that awareness and automaticity can be studied adequately only within the notion of *skill*.

A direct consequence of the outlined (vulnerable) theory is the adequacy of studying linguistic *behaviour* in written language. By studying reading and writing behaviour without *a priori* assumptions about the relationship between spoken and written language, we focus on the activity where the problems of dyslexics become the most visible (see Uppstad, 2006b for a suggestion of how this can be done). This means approaching dyslexia through a study of symptoms e.g. in accordance with psychiatric diagnosing system DSM (Tønnessen, 1997). When searching for the causes of dyslexia in spoken language, we should provide definitions without causal factors which should be treated as hypotheses in daring falsification designs.

CONCLUSIONS

In this article we have focused on the dominant conception of ‘phonology’ in cognitive psychology. We have claimed that the theory of phonological awareness has a definition of ‘phonology’ which is not suitable to empirical research, owing to its vagueness and empirical status. Further, we have investigated the attempt by Tallal and her co-workers to stretch the notion of ‘phonology’ towards perceptual and auditory aspects. We have claimed that this approach lacks a useful level of generalization of language structure, and that the criteria of empirical science have not been met. Definitions of ‘dyslexia’ should be based on symptoms and should not include causes such as ‘a phonological deficit’ (Tønnessen, 1997), because then we delimit the search for causes and risk circular reasoning. E.g. if we include ‘phonological deficit’ in the definition of ‘dyslexia’

and sample dyslexics on the basis of this definition, then it is not surprising that we find a high frequency of phonological deficits among dyslexics. To the extent that notions such as 'phoneme' and 'phonology' are included in hypotheses, their status must be clarified and they must be operationalized according to commonly accepted standards of empirical science.

In Karl Popper's concept of 'falsification', we find the illustration of the black swan falsifying the statement 'all swans are white'. Still, the enterprise of falsification is not as simple as it may seem, because one must verify that the black swan truly is black and that it truly is a swan. In other words, we need to investigate whether deaf people's reading ability corresponds to the exceptions that Popper illustrates with the black swans. Faced with this population within the literate community, phonology according to any precise, scientific definition cannot be seen as either necessary or sufficient for the ability to read. Proponents of the phonological-deficit hypothesis have chosen either to ignore this fact or to use non-empirical theory to explain it away. For the proponents of the phonological-deficit hypothesis, some central challenges must be met: (1) Can the hypothesis be formulated in such a way that it can be falsified? and 2) Which empirical findings could falsify the hypothesis?

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