Department of Phonetics and Linguistics

SPEECH AND NONSPEECH AUDITORY ABILITIES IN TWO CHILDREN WITH DISORDERED LANGUAGE

Stuart ROSEN, Heather VAN DER LELY and Susan DRY

Abstract
It has often been claimed that deficits in nonspeech auditory abilities can be responsible for various language disorders, especially for specific language impairment (SLI). We have thus investigated the auditory perceptual skills of two teenage boys with very different language disorders. 'AZ' has a severe language impairment (probably of genetic origin), but otherwise normal (or above normal) cognitive abilities. 'W' has Landau-Kleffner syndrome, an aphasia acquired in childhood, and typically associated with auditory verbal agnosia and abnormal EEG. Two nonspeech auditory tasks were used (temporal order judgement and backward masking), because they have been claimed to differentiate SLI from control children in previous studies. In addition, a simple same/different word discrimination task was run. 'W' showed essentially normal performance on the temporal order judgement task, but much more susceptibility to backward masking than a control group. He also exhibited what appeared to be diminished frequency selectivity. 'W' also made a significant number of errors on the same/different speech task, but improved on this task when the stimuli were artificially lengthened. At least part of his language problem thus appears to be auditory. 'AZ', on the other hand, showed essentially normal performance in *all* tasks. Thus, SLI can occur in the absence of any auditory disability, lending support to the claim (when placed in the context of other evidence) that SLI can be caused by a highly specific deficit in a language "module".

1. Introduction
Specific Language Impairment (SLI) is a disorder in which language acquisition is impaired in an otherwise normally developing child. Its incidence is approximately 7% (Leonard, 1998). There is currently much controversy over the extent to which SLI can be caused by, or associated with, auditory perceptual disabilities that are not specific to speech. That an auditory processing disorder is the root cause of SLI is most commonly associated with Tallal and her colleagues, who have promulgated this view for 25 years.

Tallal and Piercy (1973), for example, used the so-called repetition task to investigate the perception of pairs of 75-ms complex periodic tones which differed only in fundamental frequency (100 Hz vs 305 Hz) as a function of interstimulus interval (ISI). The crucial finding was that SLI children had no difficulty in identifying the order of these stimuli as long as the ISI between them was long (>150 ms). When made shorter than this, however, performance worsened considerably. Control children, with normally-developing language, showed much smaller effects of ISI, although they still did worse at the shortest ISIs. SLI children showed a relative impairment at short ISIs even when they were not required to label the order of the two stimuli, but simply to say whether they were the same or different.

More recently, Wright *et al.* (1997) have shown what appears to be an even more robust effect, with no overlap in the performance of SLI and control children on a backward masking task. (One of the difficulties in interpreting Tallal's early work is the use of group means, so it is impossible to tell if auditory processing is impaired in *all* SLI listeners.)

Such claims are of more than theoretical importance, of course, in that they have enormous implications for rehabilitative therapy. And, in fact, there are reports that auditory training can, in itself, result in improved language abilities (Merzenich et al., 1996; Tallal et al., 1996).

In contrast, there is the view that SLI represents a specifically *linguistic* (grammatical) disorder, with no requirement that auditory processes be deficient (*e.g.* see van der Lely, 1997). In order to assess this view, we have tested a boy with SLI on the two auditory tasks that have been claimed to distinguish SLI from normally-developing children. We have in addition run a same/different speech perceptual task using real words. Half of the word pairs in this task were artificially lengthened to double their duration, as there have been claims that such lengthening can improve the speech perceptual capabilities of listeners who have difficulties with this task (in particular, in the population of SLI children - Tallal and Piercy, 1975).

We have also run these same tasks on a boy with Landau-Kleffner syndrome, also known as acquired aphasia with convulsive disorder. Although there is no doubt that the primary feature of Landau-Kleffner syndrome is its impact on language, there is no reason to suppose that this language disorder is related in any way to SLI. Part of the reason for including such a child in this study is that there has been very little investigation of the nonspeech auditory capabilities of such children, even though it is well known that speech perceptual difficulties can be severe. It would therefore be important to know, not least from the point of view of designing appropriate rehabilitative strategies, the extent to which auditory problems are only speech-related, or also affect nonspeech sounds. It is also interesting to note at least one report that adult aphasics with left hemisphere damage from focal brain lesions show good correlations between a measure of language comprehension (which also taps speech perceptual abilities)[1] and performance in the repetition task for nonspeech sounds differing only in fundamental frequency at short ISIs (Tallal and Newcombe, 1978).

[1]The measure used was the *Token Test* (DeRenzi and Vignolo, 1962), which is not a simple task of speech perception, but requires the listener to respond to specific commands. Although 'language comprehension' is clearly necessary to do well on this task, it is *not* straightforward to interpret errors, which could arise from deficits in speech perception, auditory memory or syntactic competence. Like many tasks of its ilk, it fails to distinguish different levels of language processing.

2. Listeners

Two boys with quite different language disorders were the focus of the present research. AZ, aged 15:6 at the time of this study, is classified as having a specific language impairment (SLI). AZ has been the focus of an extensive series of investigations concerning his cognitive and linguistic abilities, which may be found in van der Lely (1997). Briefly, AZ appears to have normal or above average abilities in non-linguistic tasks, and in verbal tasks that rely on pragmatics or analogical reasoning; estimates of his nonverbal IQ range between 119 and 132 on standardised tests. On the other hand, he is severely impaired in tasks concerned with inflectional morphology and syntax. He, and a group of 15 children like him, have therefore been labelled as exhibiting *grammatical SLI* to emphasise the domain of the disability (van der Lely and Stollwerck, 1997).

William (hereinafter referred to as W) presents a very different picture. Aged 14:6 at the time of this study, W had normal development until age 3:6 when his speech and language deteriorated unexpectedly. As W passed a free-field distraction hearing test, demonstrated auditory verbal agnosia, and his EEG recordings showed spiking, he was diagnosed as having Landau-Kleffner syndrome. He later also experienced some petit-mal absences, and was medicated for a time with steroids. W attended a school for children with severe speech and language difficulties at age 5:2, and progressed to a partially-hearing unit (a signing environment) by age 8. When he became less reliant on signing, he transferred to a school for deaf children that used oral communication. W, too, has been extensively investigated for a number of years (Dry, 1997; Vance, 1991; Vance, 1997).

For the masking task, there was also a control group of 10 children in the age range of 12-16 years (mean of 13:3), with no history of a hearing, speech, language or literacy disorder, nor with any emotional/behavioural difficulties. These were recruited primarily from the children of UCL staff through an advertisement, and through word-of-mouth.

3. Methods

3.1 Temporal order judgement

The temporal order task was modelled closely on that described in Tallal (1980), where further procedural details may be found. Only a brief description is given here. A number of studies by Tallal and her colleagues appear to use essentially the same stimuli and techniques (*e.g.*, Tallal and Piercy, 1973).

The basic stimuli were two 75-ms complex periodic tones with equal amplitude harmonics, and with fundamental frequencies of 100 and 305 Hz. Listeners were first trained to respond differentially to the two stimuli presented on their own (by clicking one of two unlabelled rectangles on a computer screen with a mouse). After reaching a criterion performance of 20 of 24 consecutive stimuli correctly identified, listeners proceeded to be trained to respond to two stimuli presented sequentially with an interstimulus interval (ISI) of 428 ms. All 4 possible stimulus orders were presented (low-low, low-high, high-low, high-high), and listeners responded by clicking the mouse sequentially on the two appropriate rectangles in the correct order. A test of 24 trials without feedback with the same stimuli concluded the training.

The ability of the listener to perform this task was then tested for pairs of stimuli separated by a range of ISIs: 8, 15, 30, 60, 150 and 305 ms. Each of the four orders were paired with each of the 6 ISIs for a total of 24 trials, presented in a random order without feedback.

The same stimuli could also be presented in the context of a same-different discrimination task. Here, the listener was asked simply to indicate whether the two sounds were the same or different (by clicking on a picture of two green circles, or a yellow circle and a red triangle). As in the identification task, training to criterion performance with sounds separated by 428 ms preceded testing with shorter ISIs.

All aspects of stimulus presentation and response collection were controlled by computer. Stimuli were presented binaurally over Sennheiser HD414 headphones in a quiet room.

3.2 Backward and simultaneous masking

The masking tasks were modelled closely on those described by Wright et al. (1997), with identical stimuli and some minor differences in the adaptive tracking procedure.

Masked thresholds were measured using a two-interval two-alternative forced choice task, using an adaptive procedure based on maximum likelihood and tracking 90% correct. On each trial, two 300-ms bursts of masking noise were presented with an 800 ms ISI. Along with one of the noise bursts occurred the 1-kHz sinusoidal probe tone. The listener indicated which of the noise bursts was associated with the probe by pressing one of two buttons on a response box. Feedback was given by lighting the correct button. Masking noises were either bandpass (0.6-1.4 kHz) or bandstop (0.4-0.8 kHz and 1.2-1.6 kHz) at a spectrum level of 40 dB. The probe could be either 20 ms or 200 ms long. The long probe always began 50 ms after the start of the masking noise. The short tone could occur either simultaneously with the masking noise (200 ms after masker onset) or with its onset 20 ms prior to the start of the masker (leading to no physical overlap between the probe and the masker - *backward* masking). All stimuli were gated with 10-ms cosine-squared envelopes.

All aspects of stimulus presentation and response collection were controlled by computer. Stimuli were presented monaurally in the right ear over Sennheiser HD475 headphones in a quiet room.

All listeners were first acquainted with the experimental situation by being tested with the long probe tone in the bandpass noise, and some listeners were also tested with the bandstop noise. Following this, the short probe was presented simultaneously with the bandpass and bandstop noise. Finally, the backward masking task was introduced. Measured thresholds were accepted as long as two of them in the same condition were within 10 dB. At least two 'good' thresholds were obtained for each control listener, except for the backward masking task, where three were obtained. AZ was sufficiently consistent in his thresholds for the '10-dB rule' also to hold, but W was more variable in performance (details below). For the same reasons (and due to pressure of time), it was not always possible to collect a sufficient number of consistent thresholds for W in all conditions.

3.3 Same/different speech task

The speech-perceptual test used the same/different format for ease of response by the listeners. The stimuli were all naturally uttered real words, originally recorded in an anechoic chamber by a female speaker of Southern British English. On each trial, a pair of words was presented. The listener decided whether the two words were the same or different, and indicated their judgement by pointing to one of two icons on a computer screen, and pressing the mouse button. A "same" response was indicated by a picture of two green circles, while that for "different" was a red triangle and a yellow circle.

A total of 7 word pairs were used in the test, with an extra pair used for practice items at the beginning of the test. In six of the seven words pairs, at least one of the words contained a consonant cluster. The other word of the pair was obtained either by deleting the second consonant in the cluster, or substituting for it with another consonant, forming a minimal pair:

DELETION: blow/bow; fog/frog

SUBSTITUTION: scar/star; skip/slip; smack/snack; spill/still

These particular pairs were chosen because they were found to be the most easily confused by a group of dyslexic children (Adlard and Hazan, in press).

The seventh pair - cat/mat - was chosen because the single initial consonants (which tend to be discriminated more easily than consonants in clusters) differed in voicing, place and manner, thus increasing their discriminability further. This pair can thus function as a "control". In particular, if a listener performs poorly for all pairs, including this "easy" pair, we might suspect a lack of attention to, or understanding of, the task. Another "easy" pair - boat/coat - served for four practice trials at the start of the test session.

Each pair occurred in both "same" and "different" trials. Two tokens of each word were recorded, so that "same" stimuli were not physically identical. Each pair was presented twice as a "same" pair, and four times as a "different" pair. For the pair skip/slip, for example, the possible pairs were:

$still_1$	$still_2$
$spill_1$	$spill_2$
$still_1$	$spill_2$
$still_2$	$spill_1$
$spill_1$	$still_2$
$spill_2$	$still_1$

where the subscript refers to a particular token.

In addition to these "normal" conditions, stimuli were also processed so as to double their duration (using the SOLA technique described by Roucos and Wilgus, 1985). There were thus a total of 84 trials in the test session, randomised for presentation (6 orders x 7 word pairs x 2 durations). The 4 additional practice stimuli contained both normal and lengthened stimuli, as well as both "same" and "different" trials.

4. RESULTS

4.1 Temporal order judgement

Both boys trained to criterion within the minimum number of trials for single stimuli, and for two stimuli presented with an ISI of 428 ms (the latter in both identification and discrimination). Both boys performed well, although not without errors, on the test itself (see Table I).

W's first attempt at the identification task, with variable ISIs, led to one error at each of the four ISIs from 8 ms to 150 ms (out of 4 trials). Interestingly, all four errors were to stimuli in the order "low-high" which were labelled "high-low". Although this might be thought indicative of a severe difficulty in temporal order judgements, a second attempt (after another 24 trials of the 428 ms ISI stimulus without error) led to perfect performance. In the same/different discrimination task, only one error was made, and this was not for the shortest ISI. W, therefore, appears to have little or no difficulty with this task, at least once he was fully acclimatised to it.

If anything, AZ performed at even higher levels. In each of two sessions of the identification task, he made a single error at an ISI of 15 ms, following which he performed perfectly on the discrimination task. Further evidence that AZ had no special difficulty with short ISIs can be found in a further test in which the stimuli were two sinusoidal tones (1 kHz and 2 kHz). Here, ISIs ranged from 305 ms down to 0 ms (*i.e.*, the two tones were presented with no gap between them). All other aspects of the stimuli and testing were unchanged. For these stimuli, AZ made one error in the discrimination task (at 15 ms) and one in the identification task (at 60 ms). Overall, then, he performed perfectly for 16 trials at ISIs of 0 and 8 ms.

listener	*type*	*number correct (of 4) for given interstimulus interval (ms)*					
		8	*15*	*30*	*60*	*150*	*305*
W	ID	3	3	3	3	3	4
		4	4	4	4	4	4
	DISC	4	3	4	4	4	4
AZ	ID	4	3	4	4	4	4
		4	3	4	4	4	4
	DISC	4	4	4	4	4	4

Table I. *Results from the temporal order judgement task for each of the two listeners. 'ID' indicates the identification task (which required two responses) whereas 'DISC' indicates a task in which the listener simply indicated whether the two stimuli were the same or different.*

Most of the temporal order judgement studies have focused on children younger than the two here (typically up to about 10 years old). However, Lincoln et al. (1992) tested a group of SLI adolescents and young adults (mean age of 17.7 years, with a range of 15-20) and still found impaired performance relative to a control group (mean of about 87% compared to 96% for a two-tone sequences, averaged over ISIs of 0, 15, 20, 60 and 150 ms). Although our results are not strictly comparable (and the tone duration is not stated explicitly by Lincoln et al.), it would appear that our two listeners are performing as well as do the controls in the Lincoln et al. study.

4.2 Backward and simultaneous masking.

Results from the masking tasks with the bandpass noise can be found in Figure 1. The largest differences among listener groups are found in backward masking. The worst performance by far is that reported for a population of SLI children by Wright *et al.* (1997). AZ's thresholds appear to be perfectly normal, both in comparison to the control group of Wright *et al.* as well as our own (and it is comforting to note that the median performance of these two groups is reasonably similar across *all* conditions). W, however, had elevated thresholds both for backward masking (about 15.5 dB greater than our controls) and for simultaneous masking with the short probe (about 6 dB greater). Unfortunately, time did not permit the collection of sufficiently consistent data for the long probe.

Statistical analysis of our own results (*i.e.*, excluding Wright *et al.*'s data) took the form of three separate one-way ANOVAs (one for each masking condition). Group differences were found both for backward masking (p0.0011) and for the short probe ($p<0.0001$). AZ's thresholds were not significantly different from the controls for the long probe (p0.33). Tukey's *post-hoc* studentized range tests showed W's thresholds to be significantly higher than AZ's and the controls, with no difference between AZ and the controls, in the other two conditions.

As mentioned above, W exhibited greater variability in performance. But it is *not* the case that his performance improved in backward masking over sessions. The data reported here represents the first three thresholds measured in that condition; his performance deteriorated significantly after this. In a further 5 threshold determinations, only one was near the mean of the first 3 measures (57.4 dB SPL compared to a mean of 64 dB) whereas the other 4 were at least 20 dB higher, with a mean of 82.9 dB SPL.

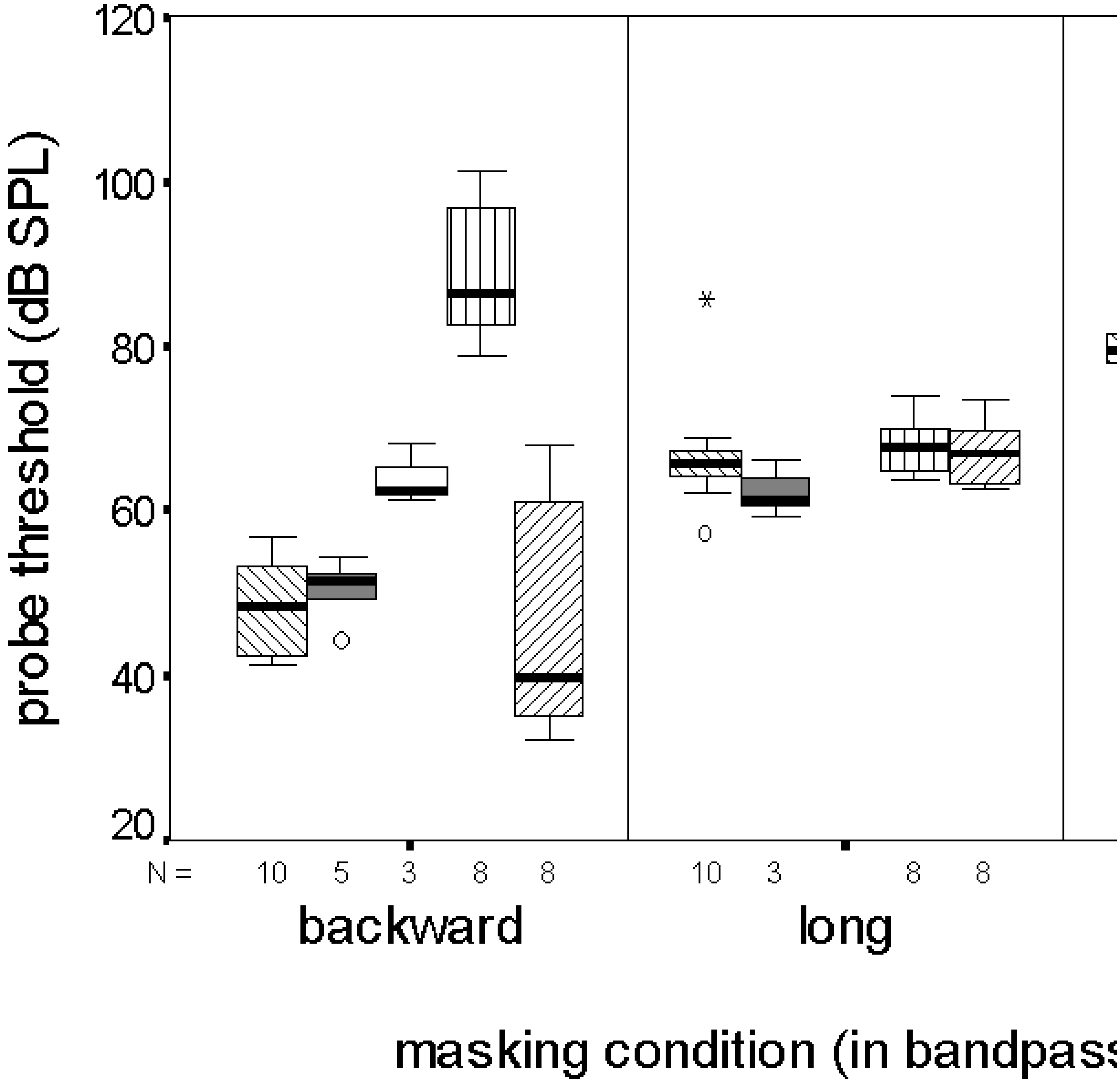

Figure 1. *Boxplots of the masked thresholds for a 1 kHz tone in the presence of a bandpass noise for backward masking and two simultaneous masking conditions. The box indicates the inter-quartile range of values obtained, with the median indicated by the solid horizontal line. The range of measurements is shown by the whiskers except for points more than 1.5 (indicated by 'o') or 3 box lengths ('*') from the upper or lower edge of the box. The short probe was 20 ms, whereas the long probe was 200 ms. Both were presented simultaneously with the masking noise after some delay from its onset. In the backward condition, the probe was 20 ms long but presented just before the onset of the noise. The data from AZ and W are individual thresholds whereas a single mean was calculated for each of the listeners in the other groups. SLI and controls are data reported by Wright and colleagues (Wright, 1998; Wright et al., 1997).*

Performance in the bandstop condition is shown in Figure 2. As for the bandpass noise, AZ appears to have perfectly normal thresholds, whereas W (who only gave sufficient data for the short simultaneous probe) has quite high thresholds, even in comparison to Wright *et al.*'s SLI listeners. Note too that W was quite variable in this condition with thresholds distributed fairly evenly over a 20 dB range. Again, one-way ANOVAs of our data support these observations - only for the short probe are there group differences ($p<0.0001$), with W's thresholds higher than those from AZ and the age-matched controls, who in turn do not differ.

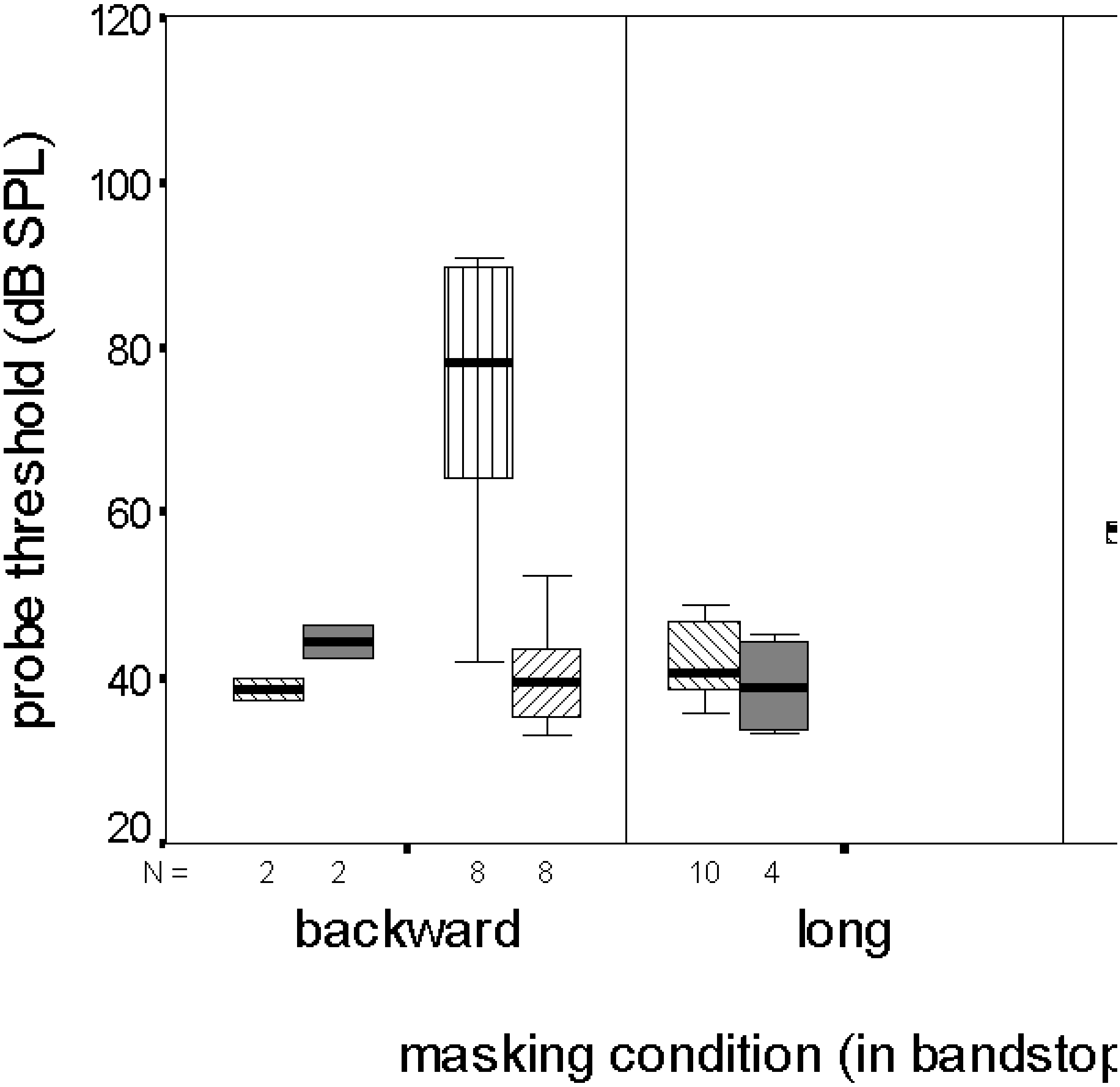

Figure 2. *Boxplots of the masked thresholds for a 1 kHz tone in the presence of a bandstop noise, for three different masking conditions. Details as for Figure 1.*

One final measure of interest from the simultaneous masking studies concerns the difference between thresholds in the bandpass and bandstop noise. This value can be considered a measure of frequency selectivity, with larger differences indicating greater selectivity (see Rosen and Stock, 1992, for the use of a similar measure). Figure 3 shows the results of this calculation. Again, AZ shows performance similar to the controls, and there is good agreement for the results of our control listeners and those used by Wright *et al*. Strikingly, both W and the SLI children show degraded selectivity, as was noted by Wright *et al*.[2] This is all the more surprising insofar as frequency selectivity is meant to be determined primarily by peripheral processing in the cochlea, which should be unaffected in SLI and Landau-Kleffner syndrome. It may be that this deficit only appears for short tones, and is due to a more central attentional mechanism. Unfortunately, neither we nor Wright *et al*. have data pertaining to the degree of selectivity obtained for long tones, which are more typically used in studies of selectivity.

[2]Although W's index for selectivity with the short probe is about 2.6 standard deviations lower than the mean obtained for the age-matched controls, a one-way ANOVA for the short failed to find any group differences, presumably because of the small number of measurements available.

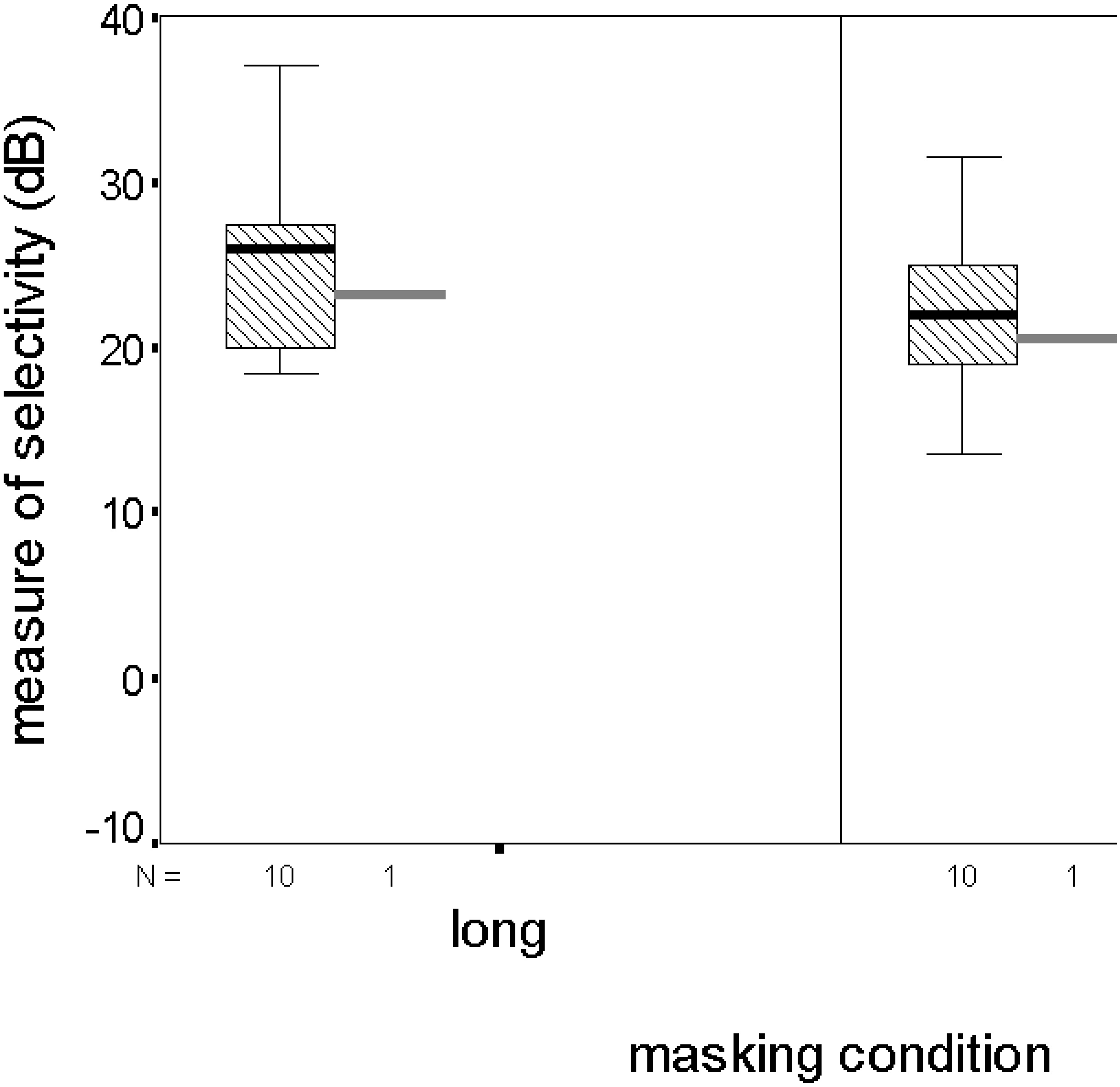

__Figure 3.__ Boxplots of the difference between masked thresholds for a 1 kHz tone in the presence of a bandstop and a bandpass noise, for two different masking conditions. Because means were taken over conditions within each subject before subtracting, there is only one value (indicated by a horizontal line) for AZ and W.

4.3 Same/different speech task.

Table II shows a break down of the performance obtained in the speech test. Unfortunately, we do not have results from a matched control group on precisely the same task. However, results from younger children, and from similarly aged children to W and AZ on a slightly shorter version of the same task, lead us to expect performance to be over 90% correct.

Both boys performed perfectly on the 'easy' pairs of stimuli, indicating a reasonable degree of attention to the task. W made a significant number of errors, with a 30% error rate for the normal stimuli. Interestingly, he performed somewhat better on the lengthened stimuli. The majority of his errors in both cases was in labelling 'different' stimuli as the 'same'. There appears to be no pattern to AZ's few errors, with equal numbers on 'same' and 'different' pairs, whether the stimuli were lengthened or not.

listener	normal			lengthened		
	same (of 12)	different (of 24)	mean (%)	same (of 12)	different (of 24)	mean (of 36)
W	11	14	69.4	11	18	80.6
AZ	11	23	94.4	11	23	94.4

Table II. *Results from the same/different speech task. Integers indicate the number of trials correct for 'same' and 'different' word pairs, whereas mean performance is given as a percentage (out of 36 trials).*

5. Summary and discussion

Although there is much more that could be done, the pattern of results across the two boys seems fairly clear. AZ appears to show completely normal performance on all the auditory tasks run, whether they concern speech or nonspeech. Thus SLI can occur in the absence of an auditory disability (especially those implicated by Tallal and Wright). This finding lends support to the notion, when placed in the context of a wide variety of other evidence, that SLI can be caused by a highly specific deficit in a language (grammar) "module" (van der Lely, 1997). It may, of course, be claimed that an auditory disability *did* exist for a crucial stage of AZ's development, but that the auditory disability has resolved. This seems unlikely given the pervasiveness of AZ's linguistic impairment - one that does not appear to be lessening to any significant degree over time, even in the face of normal auditory processing. What these results even more clearly rule out is the possibility that an auditory training programme will alleviate any of AZ's linguistic difficulties (contrary to various claims - Merzenich et al., 1996; Tallal et al., 1996). It must be emphasised that AZ shows the linguistic characteristics frequently reported for SLI children, and is not atypical of children with persisting language impairment. Therefore, these findings may shed light on the connection between SLI and possibly co-occurring auditory perceptual deficits. There may, in fact, be no causal relationship.

On the other hand, auditory training may have some role in the rehabilitation of W, insofar as he does appear to show some auditory processing problems both for speech and nonspeech. Also, lengthening of the speech stimuli (part of the manipulations done by Tallal et al., 1996) appeared to help his discrimination, which in our limited experience is unusual. In a pilot study of a slightly shortened version of this same speech task in different levels of background noise, there was never an advantage for the lengthened stimuli for normal children (aged 5-12), even when performance levels were around 60% due to the noise. It may thus be that improved performance with lengthened stimuli of this sort is direct evidence of a specific type of speech perceptual difficulty.

It is important to note that W exhibited deficits in a variety of speech-perceptual tasks, not only in the one reported here (Dry, 1997). For example, he scored at least 4 standard deviations below the mean of a control group in another pair of same/different word discrimination tasks involving words or nonwords. Here, contrasts were made word-finally as well as word-initially, and for a variety of phonetic changes (*e.g.*, solely in voicing). Also, he scored about 1.5 standard deviations below the published standards for 11 year olds in the Auditory Discrimination and Attention Test (ADAT - MorganBarry, 1988), in which a single word of a minimal pair is uttered, and the appropriate picture must be pointed to.

Therefore, the evidence for an auditory processing difficulty in this case appears inescapable. There may, of course, be other factors in W's language difficulties, but improvement even at this level of processing could only be an assistance to W in everyday life.

What is not at all clear is the relationship between performance on the nonspeech and speech tasks, nor even between the two nonspeech tasks themselves. Although it seems reasonable to suppose that an abnormal degree of backward masking would impair performance on the temporal order judgement task, the story is not so simple. Wright *et al*. (1997) found reduced backward masking in their SLI group in the bandpass noise, and normal backward masking in another group of SLI children when the notch in the bandstop noise was made sufficiently wide. So there is only abnormal backward masking to the extent that the masker and the probe are similar in frequency. It should therefore be expected that listeners with auditory processing difficulties could be impaired on a temporal order judgement task with complex periodic stimuli with similar spectra (as are typically used) but not with two sinusoids that are sufficiently far apart in frequency (as in the stimuli mentioned above).

Even had we found impairments in the temporal order judgement task, it would be difficult to say what that would actually mean. Such a task is very similar to those studying *auditory streaming*, which concerns the way in which the auditory system assigns acoustic components to distinct sources (for a very interesting review of this entire area, see Bregman, 1990). In the simplest cases, a series of pure tones in two separated frequency regions is played at different rates. At low rates of presentation, the sequence is heard as a single *stream* of tones. At high rates, however, the separated frequency regions separate into two separate streams, which it is possible to attend to quite separately. One of the properties of an auditory stream is that it is reasonably easy to tell the temporal order of tones within a stream, but difficult or impossible across streams. Streaming occurs, of course, not only for pure tones, but for stimuli which can vary in a large number of ways (*e.g.* spectral shape or fundamental frequency). Given the large difference in fundamental frequency typically used in the order judgement task (some 1.6 octaves), we should expect the tones to separate into separate streams. In fact, it was the perceptual experiences of one of us while doing the task (SR) that made it apparent that temporal order judgement must be related to streaming (at least for normal listeners).

On the other hand, although it seems likely that streaming phenomena may be at the heart of the inability of normal listeners to make temporal order judgements of the kind explored here, this may not be the case for listeners who are poor at the task. In particular, would we want to claim that SLI children who are impaired on this task are more susceptible to stream segregation, insofar as we generally think of streaming as a 'good thing', essential for auditory perception? And there does seem to be evidence that hyper-normal streaming may not be at the root of impaired temporal order judgements. In particular, there is the claim that listeners impaired on temporal order judgements are just as impaired simply in labelling the two-tone stimuli as the 'same' or 'different' (*e.g.* Tallal, 1980; Tallal and Piercy, 1973). Therefore, the problem has been labelled as 'difficulties in the processing of basic sensory information entering the nervous system in rapid succession (within milliseconds)' (Tallal et al., 1993). Here, the supposition is that the rapidity of the input somehow wipes out the information that allows one even to identify the stimuli. It seems likely that for normal listeners it would be possible to make stimuli short enough to interfere with accurate order judgements without necessarily compromising a judgement of 'same' vs. 'different'.

Further investigation of this issue will require more difficult stimuli. The task as it stands is much too easy (at least for two-tone presentations), but it should readily be possible to make it more difficult by shortening stimuli sufficiently. It would also be advantageous to run the task adaptively at, say, a fixed short ISI, to determine the minimum stimulus duration necessary for performance at a particular level. This would be the best way to get around the problem of ceiling levels of performance preventing listener differences in acuity to be expressed.

There still remains the problem of relating the difficulties on the nonspeech backward masking task to those experienced in speech. It might be thought that this relationship is straightforward, as indicated by Tallal and Stark (1981). They explicitly suggested investigations of backward and forward masking on the basis of poor performance for some, but not all, phonemic contrasts. And some relationships do seem very straightforward. Consider first /bɑ/ vs. /dɑ/, thinking of the burst and formant transitions as the first component in the sequence, and the vowel as the second component. These two components are reasonably similar in frequency, and so we might suppose them to be difficult to distinguish (as Tallal and Stark found) if there were an abnormal degree of backward masking. But if abnormal backward masking requires the 'masker' to have a similar spectral content to the 'signal', how can we explain the difficulty SLI children had with /sɑ/ vs. /ʃɑ/ (as Tallal and Stark also found)? In this pair, the following vowels have little of the high frequency energy present in the initial voiceless fricatives. And even more problematical: If forward masking were found to be more or less normal for W, as Wright *et al.* found for her SLI listeners, why should he make the greatest number of errors in distinguishing "sum" from "sun" on the ADAT?

It may therefore be that W, as well as the children studied by Tallal and her colleagues, have a more general speech processing deficit than one simply confined to sounds occurring in rapid succession (and one that may only co-occur with, rather than be responsible for, their SLI). It is interesting to note that a similar conclusion was reached by Adlard and Hazan (in press) concerning the speech perceptual abilities of dyslexics (although no deficits were noted in a set of rather gross nonspeech auditory tasks). They found a subgroup of dyslexic children who appeared to show relatively weak discrimination skills for speech sounds, but these deficits were not restricted to phonemic contrasts that could be said to be cued by rapid acoustic cues. In fact, the children who were 'perceptually weak' tended to have the most difficulty with the same phonemic contrasts as did the normal children (*e.g.* the place contrast in nasals), only to a more significant extent.

Acknowledgements
First thanks must go to AZ and W for their willingness to undergo what are often tedious tests, and to Beverley Wright for useful discussions and for making her data available to us. Richard Baker was responsible for much of the software to run the backward masking task, while the temporal order task used a program by Andrew Simpson. Andy Faulkner improved the manuscript. The study of W and age-matched controls forms part of the M.Sc. work of Susan Dry (1997). Part of the work by Stuart Rosen has been supported by the Wellcome Trust (Grant No. 046823/Z/96) while Heather van der Lely is supported by a Wellcome Trust Fellowship (No. 044197/Z/95).

References
Adlard, A., and Hazan, V. (in press). "Speech perception abilities in children with specific reading difficulties (dyslexia)," Quarterly Journal of Experimental Psychology.

Bregman, A. S. (1990). Auditory Scene Analysis (The MIT Press, Cambridge, MA).

DeRenzi, E., and Vignolo, L. A. (1962). "The Token Test: A sensitive test to detect receptive disturbances in aphasia," Brain 85,665-678.

Dry, S. (1997). An investigation into the auditory processing and literacy skills of a boy with Landau-Kleffner syndrome. Unpublished M.Sc., University College London, London.

Leonard, L. (1998). Children with Specific Language Impairment (MIT press, Cambridge, MA).

Lincoln, A. J., Dickstein, P., Courchesne, E., Elmasian, R., and Tallal, P. (1992). "Auditory processing abilities in non-retarded adolescents and young adults with developmental receptive language disorder and autism," Brain and Language 43,613-622.

Merzenich, M. M., Jenkins, W. M., Johnston, P., Schreiner, C., Miller, S. L., and Tallal, P. (1996). "Temporal processing deficits of language-learning impaired children ameliorated by training," Science 271,77-81.

MorganBarry, R. (1988). The Auditory Discrimination and Attention Test (NFER-NELSON, Windsor, Berkshire).

Rosen, S., and Stock, D. (1992). "Auditory filter bandwidths as a function of level at low frequencies (125 Hz-1 kHz)," Journal of the Acoustical Society of America 92,773-781.

Roucos, S., and Wilgus, A. (1985,). High quality time-scale modification for speech. Paper presented at the IEEE International Conference on Acoustics, Speech and Signal Processing.

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

Tallal, P., Miller, S., and Fitch, R. H. (1993). "Neurobiological basis of speech: A case for the preeminence of temporal processing," Annals of the New York Academy of Sciences 682,27-47.

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

Tallal, P., and Newcombe, F. (1978). "Impairment of auditory perception and language comprehension in dysphasia," Brain and Language 5,13-24.

Tallal, P., and Piercy, M. (1973). "Defects of non-verbal auditory perception in children with developmental aphasia," Nature 241,468-469.

Tallal, P., and Piercy, M. (1975). "Developmental aphasia: The perception of brief vowels and extended stop consonants," Neuropsychologia 13,69-74.

Tallal, P., and Stark, R. E. (1981). "Speech acoustic-cue discrimination abilities of normally developing and language-impaired children," Journal of the Acoustical Society of America 69,568-574.

van der Lely, H. K. J. (1997). "Language and cognitive development in a grammatical SLI boy: Modularity and innateness," Journal of Neurolinguistics 10,75-107.

van der Lely, H. K. J., and Stollwerck, L. (1997). "Binding theory and grammatical specific language impairment in children," Cognition 62,245-290.

Vance, M. (1991). "Educational and therapeutic approaches used with a child with acquired aphasia with convulsive disorder (Landau-Kleffner syndrome)," Child Language Teaching and Therapy 7,41-60.

Vance, M. (1997). "Christopher Lumpship - Developing phonological representations in a child with an auditory processing deficit," in Making New Connections: Psycholinguisitic Approaches to Therapy with Children and Adults, edited by S. Chiat, J. Law, & J. Marshall (Whurr, London).

Wright, B. A. (1998). "Specific language impairment: Abnormal auditory masking and the potential for its remediation through training," in Psychophysical and Physiological Advances in Hearing, edited by A. R. Palmer, A. Rees, A. Q. Summerfield, & R. Meddis (Whurr, London).

Wright, B. A., Lombardino, L. J., King, W. M., Puranik, C. S., Leonard, C. M., and Merzenich, M. M. (1997). "Deficits in auditory temporal and spectral resolution in language-impaired children," Nature 387,176-178.

SHL 10 CONTENTS

PUBLICATIONS

PHONETICS AND LINGUISTICS HOMEPAGE

Page created by Martyn Holland

Send E-Mail! **for comments**