Language and Cognitive Processes

Mapping theories of developmental language impairment: Premises, predictions and evidence

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This paper presents the case for a mapping theory of developmental language impairment, which branches into a theory that Specific Language Impairment (SLI) arises from impaired phonological processing and the consequent disruption of the mapping process through which the words and sentence structure of a language are established. The prelude to the case is that the mapping process, which is a *sine qua non* of language acquisition, is the first place to look for possible sources of deficits in language acquisition; that recent research on the mapping process points up the contribution of complex phonological processing not just in the segmentation and representation of lexical phonology, but in wider lexical and syntactic development; and that phonological processing is therefore a plausible source of the deficits observed in SLI. Detailed analysis of the mapping process and the role of phonological processing gives rise to specific predictions which are evaluated against wide-ranging research findings on children with SLI. It is argued that the phonological theory provides a better fit with this empirical evidence than theories which posit either specific grammatical deficits or low-level auditory processing deficits, and offers more far-reaching insights than theories which invoke a general limitation in processing capacity. The paper concludes with wider implications, further predictions, and further questions arising from the mapping theory of developmental language impairment and its particular instantiation in the phonological theory of SLI.

INTRODUCTION

It is uncontroversial that children acquiring language acquire a specific language. It is also uncontroversial that the acquisition of a specific language entails the acquisition of mappings between form and meaning which are specific to that language. These commonplace observations are the starting point for a less commonplace argument regarding theoretical approaches to impaired language development and explanations of the specific patterns of impairment observed in children with Specific Language Impairment (SLI).

The argument runs like this. The language-acquiring child is faced with a stream of speech in a ''scene'' to which the speech relates in some way. In order to discover the mappings of her language, the child must segment the stream of speech into meaning-relevant chunks, and segment the scene into speech-chunk-relevant meanings. The nature of speech chunks, meaning chunks, and their relation to each other is by no means simple, and varies significantly between languages. The task of discovering mappings in a language is therefore no mean task. Yet the majority of children crack it successfully by 3 or 4 years. Logically, they could not do this unless they were equipped with powerful capacities to make connections between form chunks and meaning chunks, and so they are. The last decade has seen breakthroughs in research on speech processing and semantic processing in early infancy which cast new light on the hypothesised capacities. The flipside of this logic and evidence is that if the capacities which underpin lexical and syntactic development are defective, the repercussions for language acquisition will be significant.

This is the starting point for the two claims to be pursued in this paper. The first is the broad claim that, since the mapping process is a *sine qua non* of language acquisition, it is the first place to look for hypotheses about impairments in language acquisition. This ''mapping theory'' of language impairment stands in opposition to grammatical theories which attribute language impairment to deficits in specific linguistic structures, and disregard possible deficits in the mapping process which might explain these. The specifics of that mapping process lead to the second, more specific, claim advanced in this paper: that linguistic deficits observed in children with SLI are due to deficits in phonological processing and their repercussions for lexical and syntactic development. This ''phonological theory'' of SLI predicts patterns of difficulty with words and sentence structure which are distinct from those predicted by grammatical theories. The different theories about the nature of impaired language development can therefore be evaluated against the patterns of difficulty observed in language-impaired children.

PRECURSORS OF THE MAPPING THEORY

The mapping theory which lies at the heart of this paper draws on a strand of child language research which starts with Slobin's (1973) pioneering work on the "cognitive prerequisites for the development of grammar". The seven "operating principles" which emerged from this initial exploration represent an early attempt to characterise the cues children use to discover the mappings of their language, and remain influential. Such piecemeal strategies have, though, been superseded by more integrated approaches and hypotheses. Their emergence is apparent in Gleitman and Wanner's (1982) chapter charting the "state of the state of the art" in language acquisition. Although the issue explicitly targeted by this chapter is the process of *grammar acquisition*, the bulk of the discussion is about *mapping processes*. The question of how the child acquires the adult grammar is addressed in terms of precisely the three mapping problems identified above: how the child goes about "extracting meaning from the situation", "extracting form from the sound wave", and subsequently "projecting a system that maps between the sounds and the meanings". The discussion of the cues which children may use to solve these problems presages much of the recent research on which the present paper draws.

Bates and MacWhinney (1987) also focus on the "mapping problem", but from a rather different angle. Their "competition model" is primarily concerned with the extent to which children use different cues, rather than what those cues are. Hypotheses about the relative validity of cues in different languages leads to predictions about order of acquisition. The effects of cue validity are tempered by constraints which stem from the child: the readiness of the function to be mapped onto a form, and the cost of perceiving and integrating a cue. In common with the competition model, and in contrast with typical modular models, the mapping theory predicts effects of impairment crossing levels of language, rather than confined to specifically phonological, semantic, or syntactic modules. In contrast to the competition model, with its focus on the validity and strength of cues, the mapping theory looks to the *types of cues* which are problematic for the language-impaired child and the ramifications through the mapping process.

The broad claim embodied in this mapping theory also finds echoes in earlier approaches to language impairment. The assumption that deficits must be traced to some point in the form-meaning relationship is embedded in Bloom and Lahey's (1978) distinction between disorders of form/content/use and the interaction between these. Coming from a somewhat different tradition which sees specific levels of language such as grammar as the main means of identifying language disability, Crystal

(1987) points out that *interactions* between levels of language may be central. He proposes a ''bucket'' theory in which ''An extra 'drop' of phonology (syntax, semantics etc.) may cause the overflow of a 'drop' of syntax (semantics, phonology etc.)'' (p. 20).

What differentiates the proposals in the present paper is the *specification of the mapping process* afforded by advances in psycholinguistic theory and by a wealth of recent research on pre-linguistic and linguistic development; and the consequent *specification of possible breakdowns in the mapping process*, in particular, the specification of the ''phonological theory'' of SLI and its predictions for lexical and syntactic deficits. These predictions are distinct from the predictions which flow from grammatical theories of SLI. The following sections of this paper amplify each step in the argument for a mapping theory of language impairment in general, and a phonological theory of SLI in particular, and work through the empirical evidence bearing on these.

THE NON-TRIVIAL NATURE OF THE MAPPING PROCESS

Phonological segmentation

Children must discover words from the utterances they hear. These typically consist of a combination of words, rather than a word in isolation (Morgan, Shi, & Allopenna, 1996). Even when mothers are asked to teach their infant a new word, they are more than likely to present the target word within a multiword utterance (Aslin, Woodward, LaMendola, & Bever, 1996). Either way, the child has the task of segmenting the utterance into meaning-relevant phonological chunks: even given utterances of a single word, she cannot know a priori that these *are* single words. Utterances such as /ˈpækɪt/ and /ˈpæk ɪt/, /fəˈgɛtɪŋ/ and /fə ˈgɛtɪŋ/ do not come tagged as one or two form-to-meaning chunks. Aslin et al. (1996) point out that mothers used pairs such as ''this shoe'' and ''tissue'', where the acoustic information at the word boundary was the same as that present within the word. In the absence of explicit tagging of word boundaries, such as pausing between word forms, speech input must contain more subtle cues of a sort which pre-linguistic infants must perceive and must use to start the ball rolling. The challenge of explaining how this happens has been widely acknowledged in child language research (see for example Chiat, 1979; Cutler, 1994, 1996; Echols, 1996; Peters, 1983). It has been met with a close scrutiny of the cues to segmentation which the speech signal may provide, both within and across languages, and a plethora of investigations into whether and when infants are able to notice those cues and use them to identify units and boundaries.

Before the infant has acquired lexical forms, and as a prerequisite to their acquisition, the only possible source of information about word units lies in their *rhythmic* and *segmental* characteristics. Salient points in the rhythmic structure of speech input may act as beacons signalling the presence of a word. Accordingly, it has been proposed that children use stressed syllables to locate word units and phrase- and clause-final lengthening to locate word boundaries (Echols, 1996; Gleitman & Wanner, 1982). Cutler (1996) suggests that children exploit the characteristic rhythm of their language to identify lexically significant chunks, and that in English, this means assuming that any strong syllable in the input is a word unit. The cues provided by rhythmic structure may, on the other hand, be construed as cues provided by vowels, since it is vowels that indicate the relative weight of a syllable and therefore carry the rhythm of an utterance. Mehler, Dupoux, Nazzi, and Dehaene-Lambertz (1996) argue that ''vowels are the cornerstone of prosodic representation in young infants'' (p. 112).

Investigations into infants' speech perception between birth and first words have demonstrated stunning sensitivities to speech rhythm and vowel quality which are in keeping with their proposed role in word segmentation. On the basis of a variety of experiments which use habituation-dishabituation and preferential listening techniques, Mehler et al. (1996) conclude that neonates are able to distinguish sentences spoken in two different languages, and show a preference for their native language. Since they can do this even when the input is filtered so that only the information carried by the lower 400 Hz of the spectrum is available, Mehler et al. claim that the infants must be relying on the prosodic properties of the input. They report further experimental findings indicating newborns' sensitivity to the presence of vowels, which carry the prosody: newborns habituated to a string of syllables notice the addition of a new syllable if it contains a different vowel from the familiar syllables, but not if it contains a different consonant. Two-month-olds, on the other hand, notice both.

At the later age of 9 months, infants have been found to favour trochaic (strong-weak) stress patterns which are characteristic of their native English (Jusczyk, Cutler, & Redanz, 1993). Early production of words shows the same preference, reflected in typical child forms such as '*mato*, '*jamas*, '*raffe* for targets *tomato*, *pyjamas*, *giraffe*. Unstressed non-final syllables are far more vulnerable to omission than stressed or final unstressed syllables (Echols, 1996).

Together, these findings depict an infant who registers complex prosodic features of speech which might serve as crucial cues to segmentation. What is the evidence that they do? Morgan and Saffran (1995) report a series of studies which investigated whether the rhythm and sequence of two syllables embedded within a trisyllabic string influence infants' grouping of

those syllables. They found that 9-month-olds amalgamated the two syllables into a cohesive unit if both the sequence of syllables and their rhythmic pattern were preserved across different contexts, but not if just one of these was preserved. For 6-month-olds, on the other hand, rhythmic consistency was enough: they treated a consistently stressed pair of syllables as an amalgam even if their sequence altered.

Infants' sensitivity to rhythmic patterns and syllable sequence as cues to segmentation is not quite the end of the segmentation story as current evidence tells it. There is one more phonological cue to segmentation, which must be the ultimate arbiter of word status: segmental consistency. By their very nature, word units are phonologically cohesive units. This means that ''the transitional probability from one sound to the next will generally be highest when the two sounds follow one another within a word, whereas transitional probabilities spanning a word boundary will be relatively low'' (Saffran, Aslin, & Newport, 1996, p. 1927). In cases where prosodic and acoustic cues leave segmentation ambiguous, only the relative consistency of a phonological sequence can vouch for its word status. Saffran et al. presented 8-month-old infants with 2 minutes of speech consisting of a stream of syllables which provided no prosodic or acoustic cues to their grouping. However, the transitional probabilities between syllables were systematically varied, providing the only possible evidence as to whether they did or did not belong together in a ''word''. After the infants had been exposed to the stream of speech, a preferential listening task was used to see if listening times for ''words'' differed from listening times for ''non-words''. It was found that they did: infants listened longer to novel syllable strings (those with low transitional probabilities) than to familiar ones (whose transitional probabilities were high). This finding demonstrates not only the precision with which infants perceive and retain sequences of syllables, but their ability to track the reliability of syllable co-occurrence across contexts, and thereby distinguish cohesive sequences from accidental juxtapositions.

The picture to date is one of infants receiving speech input which provides a range of subtle cues to segmentation; registering some of these cues from birth and others not long after; integrating them with each other; and exploiting these integrated cues to discover and store word units.

Semantic cues to phonological segmentation

It might be argued that sound is not the only source of information about word units. The child hears speech in a context, and that speech typically relates to the context in which it is produced (Snow, 1995). The child's understanding of that context and of the connection between utterance and context are essential if she is to have some chance of discovering the

meaning of the utterance. More than this, though, her understanding of the context might focus her attention on elements of the context to which words refer, and thereby act as a prompt to find word forms corresponding to those elements. The ideal scenario for this type of "semantic bootstrapping" is the "joint attention episode" (Moore & Dunham, 1995): the child picks up a car and the speaker says "That's a car". The child assumes the speaker is talking about the object on which they are both focused, and this leads her to search for a phonological form for that object in the speech she hears.

But even this ideal scenario has shortcomings which make it less than adequate for word acquisition. A semantically driven search for a word phonology does not automatically lead to the target phonology. This will only happen if the child recognises every other word in the utterance and can eliminate these from her search. Even if she solves the phonological segmentation problem in this way, she still faces the semantic segmenta- tion problem. As has long been recognised by philosophers of language, the sense of a word is not the same as its reference. Discovering what *car* refers to is not the same as discovering what *car* means. It might mean "vehicle", or "car", or "thing with wheels", for example. The ideal scenario is not enough to delimit the semantic boundaries of a word.

It could help, though, if children bring more to the joint attention episode than a simple assumption that the speaker's words label what speaker and child are both looking at. Current evidence indicates that they do. Researchers have proposed a variety of principles which direct children's hypotheses about word meaning (see Clark, 1993; Markman, 1989). These principles capture the biases in conceptualisation which children bring to the discovery of word meaning, and the assumptions children make about the mapping of lexical forms onto conceptual categories. They go some way towards explaining how children segment scenes into word-size meanings, and how they come to distinguish the meanings of words which are used to label the same referent but from different points of view (see also Clark, 1997).

Equally important, though, is the emerging evidence that children are guided not just by their own biased perspectives on the scene, but by their perception of the *speaker's* focus within the scene. Using ingenious experiments which manipulate the input of novel words, researchers have shown that, in learning a new word, infants do not have to hear the word at the point where they can see its referent and are focused on it (Baldwin, 1995; Tomasello, 1995). On the contrary, they know that a word refers to the *speaker's intended focus of attention*, and they know they must discover what that focus is in order to discover the word's meaning. When the speaker says "Let's find the gazzer", picks up one object, frowns, then picks up another object with glee, the child does not assume that the word

gazzer refers to an object in view at the moment the word is heard, or to the first object the speaker picks up (Tomasello, Strosberg, & Akhtar, 1996). Instead, she takes it to refer to the object the speaker *intended* to focus, and the speaker's frown and further search are enough to tell her this. This important finding hints at a sophistication in infants' interpretation of scenes which matches the sophistication of their speech processing, and which research has just begun to tap.

Whatever details of these early capacities eventually emerge, it is evident that they constitute a potent combination. Thanks to the convergence of phonological and semantic cues, "fast mapping" can occur after only a few exposures to a word, contributing to the rapid vocabulary acquisition observed in normally developing children (Carey, 1978). Yet this cannot be the whole story, for reasons which the next section uncovers.

Phonological cues to semantic segmentation

This rather skeletal analysis of what is involved in identifying words has already led us to attribute a great deal to the child: sensitivity to subtle phonological cues, sensitivity to the focus of attention in a scene, but also sensitivity to their co-occurrence. All this is required even where concrete nouns are the target. The challenges are compounded when it comes to other sorts of words. Consider words whose referents are not directly observable and cannot be the shared focus of attention. These include vast swathes of the vocabulary a child must acquire. Everyday verbs such as *fall*, *play*, *eat* refer to events which cannot be focused in the same way as concrete nouns (see Fisher, Hall, Rakowitz & Gleitman, 1994; Tomasello & Kruger, 1992). It is true that they have features which are open to perception, so that observation of the scenes in which these verbs occur will give some clue to their referent. But observational evidence will wildly underdetermine the boundaries of their meaning: that *fall* entails uncaused but not caused downward movement (in contrast to *drop* which can be used for both); or that *eat* entails consumption of solid but not liquid substances (in contrast to *swallow* which can be used with both). The problems are even greater with nouns and verbs which refer to non-perceptual experience. *Friend*, *idea*, *want*, *dream*, for example, refer to social or emotional or mental aspects of experience, none of which can be focused by shared gaze. Likewise, terms which refer to time and temporal relations have no observable correlate in scenes. The less a word meaning can be cued by observation of scenes, the more the child must depend on phonological cues to discover it. The acquisition of some aspects of verb meaning will depend on encounters with the same verb form across different scenes. The meaning of *open*, for example, entails a variety of distinct-looking events involving distinct-looking objects—jars, mouths,

eyes, windows, presents. Only by encountering *open* in these different contexts can its full meaning be determined.

The clearest evidence for the underdetermination of meaning by scenes, and the role of phonology in determining meaning, lies in differences we observe across languages. These are apparent even in children's earliest words. One well-rehearsed example is children's encoding of the most basic and observable of events, those involving motion and contact (Slobin, 1996). This is found to be influenced by language. In English, children's earliest utterances typically refer to such events using verb particles such as *on*, *in*, which focus on direction of movement; subsequently they combine these with verbs which focus on manner of movement: *put on*, *push on*, *push in*. To talk about the same causation of contact, the Korean-speaking child must focus less on subtle differences in direction of movement, but must notice the tightness of fit between the objects in contact, since a different verb is required depending whether the objects are brought into tight or loose contact (Choi, 1997). The English-speaking child, of course, remains oblivious to this feature of the scene.

Presumably English- and Korean-speaking children start out with the same potential to notice specific direction of movement *and* tightness of fit of objects. It is hard to see how any *semantic* cue could alert the child to the importance of these aspects of events for the purpose of talking about them. Nothing in the scene itself or in the speaker's focus of attention within the scene could spotlight the specific direction or the tightness of fit in the motion-and-contact event. If no semantic cue is available, *phonology* must be the trigger. Only their encounter with consistent phonological forms across different contexts could lead children to search for and register that feature which is significant in their language and attached to the phonological form for the event. Given the differences in English and Korean children's first references to motion events, this phonological trigger must be operating in the earliest stages of lexical acquisition.

It must continue to operate as children go on to acquire "grammatical" or "function" morphemes. Since languages vary dramatically in number and types of function morphemes, the child cannot know in advance which distinctions she should be looking to mark (see Slobin, 1985). The English-acquiring child cannot know that she should look for past and present tense markers; that she should notice the number of the subject in the case of the present tense but not the past; and that she need not notice the gender of the subject, as the Hebrew-acquiring child must. What could enable her to discover these facts about her language? The only available cue is phonology. She can only discover that past tense is marked in English if she notices the phonological variation in familiar form-meaning pairs (*walk/walked*, *laugh/laughed*), which will prompt her to "search" for the context in which that variation occurs—a temporal context. Likewise,

she can only discover the marking of present tense and agreement if she notices the occurrence of -*s* with these same form-meaning pairs (*walk/ walks*, *laugh/laughs*). But in this case, her discovery of the grammatical function depends on noticing not just the phonological form and temporal context. She must also notice semantic features of a syntactically related constituent—person and number of the head of the subject NP with which the inflected form occurs—which must themselves be phonologically cued.

Empirical support for the hypothesised role of phonology in their development comes from investigations into the effects of metrical factors on children's production of function morphemes. Gerken (1991, 1994) found that 2-year-olds' imitation of articles and pronouns depended on their position within a phonological phrase, echoing the metrical biases children show within words. When a weak function morpheme such as an article preceded a strong form, as in

he KISSED / the DOG,

children were more likely to omit it than when it followed a strong form, as in

MAX / KISSED the DOG.

This shows that children are using phonological cues to notice and/or organise their production of function words.

Phonological and semantic cues to syntax

The phonological processing which is necessary for lexical and morpho- logical acquisition is also a prerequisite for discovering how sentences are structured in the input language. From the perspective of the mapping theory, the acquisition of syntax is more than the grafting of syntactic structure (of whatever theoretical persuasion) onto the material provided by lexical acquisition. Even the most primitive syntactic combinations, in the form of typical two-word utterances preserving the word order and/or inflectional markers of the input language, require the child to have registered substantial prosodic chunks and phonological details within these. In addition, the child must have registered the relation within the scene which word order or inflections mark. If we take such word combinations to be rudimentary syntactic forms, the acquisition of syntax originates in the child's ability to weld together a prosodic arrangement of familiar word forms and a relation observed between the referents of those word forms. This proposal is reminiscent of the functionalist model proposed by Bates and MacWhinney (1987), who ''show how the native speaker learns to map phrasal configurations onto propositions, using the same learning principles and representational mechanisms needed to map

single words onto their meanings'' (p. 163). It is in keeping with the
evidence presented by Tomasello and Brooks (1999) that children's early
combinatorial patterns are lexically specific, occurring with particular
predicative terms in what they describe as ''verb island'' constructions.
What differentiates the present proposal is the specification of these
constructions as pairings between a *prosodic arrangement of words* and a
semantic relation between their referents.

The accumulation of such piecemeal pairings provides the material for
abstracting ''commonalities of both form and function'' (Tomasello &
Brooks)—in terms of the mapping theory, commonalities of prosodic-
semantic mapping. It is the abstraction of these commonalities which leads
to abstract syntactic categories such as ''subject'' and ''object'', and equips
the child with both semantic bootstraps to verb-argument structure
(Pinker, 1989) and syntactic bootstraps to verb meaning (Fisher et al.,
1994). This may be illustrated by considering the acquisition of verbs such
as ''offer'' and ''accept'', which convey alternative perspectives on the
same event:

> The clown offered a cake to the dancer/The dancer accepted a
> cake from the clown.

If the child has registered the correlation between ''entity focused as agent
in an event'' and ''noun occupying prosodic slot before event word'' (a
rudimentary notion of subject in English), this can help her gain
information about these verbs. She might notice that the speaker who
uses ''accept'' is focused on the goal (dancer) rather than the source doing
something, and use this as a semantic bootstrap, inferring that ''accept''
will take a goal argument as its subject. Alternatively, she might notice
which noun argument (dancer) occupies the subject slot with ''accept'', and
with the help of syntactic bootstrapping, infer that the verb conveys the
event from the perspective of the goal argument. Experiments carried out
by Pinker and Fisher et al. have shown that children as young as 3 and 4
can exploit both types of bootstrapping.

With semantic and syntactic bootstrapping, we have brought the child
full circle. Mappings between semantic relations and abstract syntactic
frames which are the *product* of earlier established lexical meanings and
their combinations become the *means* of establishing the semantics of
verbs and the syntactic frames in which they occur. In its totality, this
conception of the emergence of syntax most closely resembles the coalition
model developed by Hirsch-Pasek and Golinkoff (1996). According to this
model, ''Comprehension begins with a strong reliance on acoustics, moves
to a reliance on coordinated input cues from syntax, prosody, extra-
linguistic context, and semantics . . . and culminates in a reliance mainly on
syntax'' (p. 198).

From the analysis of the mapping process to the phonological theory of SLI

In the above analysis of the mapping process, phonology has figured as a key player. The child's sensitivity to prosodic structure and the phonological detail within this was critical in the segmentation and hence storage of lexical units, the identification of their semantics, and the identification of their syntactic combination. The allegedly pivotal role of phonological processing in lexical and syntactic development is the catalyst for the phonological theory of SLI.

THE CASE FOR THE PHONOLOGICAL THEORY OF SLI

In a broad review of opposing theories of SLI, Joanisse and Seidenberg (1998) question whether SLI is a specifically grammatical deficit, and argue that grammatical impairments are ''sequelae of information processing''. The gist of their argument is

> that SLI is associated with impairments in the processing of speech; that these impairments affect the development of phonological representations; and that degraded phonological representations are the proximal cause of deviant acquisition of morphology and syntax, by virtue of their roles in learning and working memory. (p. 241)

According to Joanisse and Seidenberg, disruptions in aspects of grammatical development are the end of a chain which starts with abnormal speech perception.

In a similar spirit, the phonological theory of SLI claims that impairment in phonological processing disrupts the child's progress through the mapping process outlined above, with inevitable consequences for lexical and syntactic development. It is hypothesised that children with SLI have reduced access to the phonological details within rhythmic structures which are required for the establishment of lexical forms and syntactic structures. This implies that particular syllables, and/or vowels at the core of those syllables, and/or consonants which flank those vowels will be unavailable or unstable in the child's perception, storage and/or retrieval of rhythmic chunks. The hypothesised deficit might be expected to span all levels of phonological processing, with the deficit at each level feeding into and fed by the deficit at other levels in ways which change in the course of development (see Chiat & Hunt, 1993; Constable, Stackhouse, & Wells, 1997). However, the focus of the phonological theory is the pattern of linguistic deficit arising from the proposed impairment in phonological

processing rather than the way in which the impairment spreads across different levels of phonological processing.

Predicted effects on the language of children with SLI

Difficulties with phonological processing which cannot be due to semantic or syntactic factors.   This may be evidenced by purely phonological errors in lexical output, and/or by poor performance in discrimination, judgement or repetition of auditory input.

Differential disruption of lexical, morphological and syntactic forms depending on the role phonology must play in cueing their semantics (see Black & Chiat, forthcoming).   Where the semantics of a target is close to a pre-linguistic perceptually based concept, as in the case of concrete nouns, it should be least affected. The more dependent a semantic representation is on phonological triggering, the less accessible it will be to the child. Accordingly, relational categories such as verbs and prepositions should be more difficult than concrete nouns. Within relational categories, we would expect differential difficulty, for example:

(i) Verbs referring to events which are directly observable, such as *fall*, *eat*, *open*, should be easier than verbs referring to events which are not observable, such as mental state verbs *think*, *dream*, *guess*. These mental state verbs should nevertheless be accessible: assuming that the child processes mental and emotional experiences in the same way as other people, the salience of these experiences should enable her to map an appropriate concept onto the corresponding verbs without recourse to their typically complex syntactic frame. The sentential complement they take, which could serve as a syntactic bootstrap to the verb's mental state meaning (as suggested by Fisher et al., 1994), entails phonological processing which would, by hypothesis, be an obstacle for children with SLI.

(ii) Aspects of verb meaning which do not correlate closely with experience and which can only be established through phonological and syntactic bootstrapping should be more problematic. This may result in the child acquiring aspects of a verb's meaning which can be derived from the interpretation of scenes in which it occurs, and missing other aspects. For example, the child may attach the verb *open* to certain visually distinctive events such as opening a door or a jar, and use it appropriately for those events, yet not have a generalised notion of *open* stretching across visually different events to which *open* can refer. Establishing the full meaning of

open depends on phonological bootstrapping (noticing the same-
ness of the phonological form of *open* across different visually
distinctive contexts in which it occurs). Likewise, the verb *give* may
be attached to the observable change of possession, without
establishing the perspective *give* takes on possession, which
differentiates it from *take*. This depends on syntactic bootstrapping
(noticing the position of participants in relation to the verb).

(iii) Temporal terms should be more difficult than terms relating to
experience, whether of a perceptual, mental, emotional, or social
nature.

This outline of predicted effects highlights a crucial point about the
hypothesised deficit in phonological processing: its disruption of the
mapping process through which semantic and syntactic structure grow.
The predictions of the phonological theory as construed here are therefore
quite distinct from a purely phonological hypothesis under which ''all
similar surface forms of the utterance must be affected in a similar way''
(Gopnik & Crago, 1991). Under this interpretation, the forms *nose* and
bees and *bee's* should be treated in just the same way, even though one is a
simple noun, the second a noun+plural, and the third a noun+possessive.
The phonological theory, rooted in a theory of the mapping process, makes
no such prediction. On the contrary, it predicts differential difficulty with
these forms depending how crucial phonology is to discovering their
function (see also Leonard, 1998).

*Differential disruption of lexical, morphological and syntactic forms
depending on their phonological complexity, with phonological factors
compounding the effects of semantic factors predicted above:*

(i) Within a semantic category such as temporal terms, forms which
are phonologically strong (''content'' words) should be easier than
those which are phonologically weak (''function'' words and
inflections). So, temporal adverbials *now*, *soon*, *yet* should be
easier than syllabic aspectual inflections *-ing* and *-en*; these should
in turn be easier than contracted forms of aspectual verbs *be* and
have and sub-syllabic tense inflections *-ed* and *-s*.

(ii) In languages and contexts where these function words and
inflections are phonologically more salient, they should be less
vulnerable.

Beyond the mapping process: predicted effects on ''thinking for speaking''

One observation which might be made about the predicted hierarchy of
difficulty is that the aspects of language most at risk are those which are

least crucial to the message conveyed, for example deictic distinctions
marked by determiners, tense and aspect, and perspective distinctions
marked by verb pairs such as *give* and *take*. It is possible to refer to things,
events, states, and even times without these. Hence the commonplace
description of some of these forms as having ''little'' or (misleadingly)
''no'' meaning.

This view of the more vulnerable items masks the role they play in our
construction of meaning. When we use language to convey thoughts, we
are forced to ''think them for speaking'' (Slobin, 1996): to shape our
thoughts according to the categories of our language. The meaning
distinctions selected by a particular language may, in some sense, be of
little consequence for the meanings we can convey or the thoughts we can
think. Children using English or Korean can put across events such as
putting an apple in a bowl or a plug in the bath even if their languages
demand different ''takes'' on these events. But in a different sense,
marking of distinctions may be very important for meaning and thought. It
may be the packaging of experience by language which allows us to
represent, attend to, and manipulate experience in the ways what we do
(Jackendoff, 1997). In this case, the effects of *different* linguistic packaging
may be negligible, but the effects of *missing* linguistic packaging will not. A
child who has difficulty with linguistic distinctions might then be expected
to show difficulties beyond language itself, in the representation and
manipulation of ideas.

Empirical evidence

Independent difficulties with phonology.   A variety of studies provide
evidence of difficulties with phonology *per se.* These are apparent in
children's performance on repetition tasks, where semantic and syntactic
demands are eliminated or reduced. Gathercole and Baddeley's finding
(1990) that language-impaired children have problems repeating non-
words is particularly notable. This finding has been replicated by Bishop,
North, and Donlan (1996) who observed deficits even in children whose
language difficulties appeared to have resolved. Single case studies of
language-impaired children's lexical processing have compared repetition
of words and non-words with naming and spontaneous word production
and have revealed similar levels and patterns of difficulty (Chiat & Hunt,
1993; Constable et al., 1997). If phonological processing were intact, and
difficulties were due to particular grammatical features or categories, we
would surely expect better performance in repetition than in naming and
spontaneous production.

It may be that difficulties observed in repetition are themselves the
product of more fundamental difficulties in processing auditory input. The

work of Tallal and colleagues (Tallal, Merzenich, Miller & Jenkins, 1998; Tallal & Piercy, 1974; Tallal & Stark, 1981) has provided ample evidence that children with SLI are impaired in their ability to perceive rapidly changing acoustic information of a sort required to discriminate, recognise, and produce certain phonological contrasts, at least in their early years. The relationship between these limitations in verbal and non-verbal auditory perception and the limitations observed in their repetition is currently a matter of debate and investigation (see Bishop et al., 1999). Tallal et al. (1998) refer to the ''cascading effects that rapid integration deficits have on phonological perception and production, the building blocks on which both oral and written language depend'', but the specific nature of these effects is not pursued.

Auditory difficulties such as those observed by Tallal and colleagues are not necessarily the ultimate or sole source of phonological difficulties in SLI. The evidence which has accrued on infants' early phonological processing—their sensitivity to prosodic patterns, the vowels which carry these, and the statistical probabilities of co-occurring segments—points to further possibilities. Children with SLI may have reduced sensitivity to these aspects of speech input for reasons other than a deficit in processing rapid acoustic transitions. Nor are their problems necessarily exclusive to auditory input: they may equally arise in the storage and production of phonological forms. Analysis of individual children's lexical processing by Chiat and Hunt (1993) and Constable et al. (1997), for example, revealed difficulties with phonological representation and production which could not be wholly attributed to limitations in auditory input.

Whereas difficulties with phonology are predicted by the phonological theory, it is hard to see how grammatical theories of SLI could account for them. In their defence, it may be argued that phonological difficulties are irrelevant to their claim, on the grounds that evidence of an association between phonological and grammatical difficulties does not rule out the possibility that these may be dissociated at least in some cases. Evidence for just such a dissociation is put forward by Van der Lely, Rosen, and McClelland (1998). They present a profile of AZ, a young person with SLI, arguing that this provides evidence for ''a discrete developmental grammatical language deficit'' on the grounds that it reveals a range of grammatical impairments in production and comprehension alongside normal performance on auditory and cognitive tasks. However, the profile of AZ makes no reference to his phonology apart from the observation that his speech is ''clear and without articulation errors''. We therefore lack the evidence which would be necessary to rule out a phonological deficit. The phonological theory makes the strong prediction that careful probing of phonological processing in a subject such as AZ, whose difficulties appear to be purely grammatical, *would* reveal subtle problems

with phonology (which may have been more acute at crucial stages of language development). These would emerge where efficient and effective phonological segmentation and storage are required, for example in non-word repetition and in "fast mapping" or "quick incidental learning" tasks. Though we have no relevant data for AZ, findings reported by Norbury, Bishop, and Briscoe (manuscript submitted for publication) lend some credibility to the prediction that non-word repetition would reveal problems. Their study of 20 children with SLI included syntactic tests which were instrumental in identifying AZ's specific grammatical impairment *and* the Children's Test of Non-word Repetition. Significantly, Norbury et al. found that even children who were very similar to AZ and might be taken to have a specific grammatical impairment demonstrated deficits in non-word repetition. It seems that their problems were not confined to grammar.

Relative difficulty of words. Children with SLI have problems with words, and with the "fast mapping" and "quick incidental learning" entailed in their acquisition (Rice, Buhr, & Nemeth, 1990; Rice et al., 1994), but these problems affect some words more than others. According to Leonard (1998), "Verbs, in particular, begin to show deficiencies that seem to go beyond the general lag in these children's lexical abilities" (p. 44). Children with SLI have been found to use a more limited range of verbs than language-matched controls, despite showing no difference in their *overall* lexical diversity (Watkins, Rice, & Moltz, 1993). As predicted, the use of verbs is variable in a number of respects. The verb vocabularies of the children studied by Watkins et al. were not confined to particular semantic domains, nor particular syntactic categories. Children with SLI are likely to use verbs spanning actions and perceptible states and events, but also non-perceptual events such as *think*, *pretend* (see, for example, Chiat & Hirson, 1987). Furthermore, while they show verb omissions and substitutions which do not occur in language-matched controls, these are not consistent (Chiat, 2000; Rice & Bode, 1993). Children often produce in other contexts the very verb which would have been appropriate in the context of omission or substitution. These various findings suggest that verbs pose specific problems, and are more problematic in some contexts than others, as the phonological theory predicted. Since there has been little detailed investigation into the semantic scope of the verbs these children use, or the scope of meaning which they attach to those verbs, we await further evidence to evaluate more specific predictions about the vulnerability of different aspects of verb meaning.

Relative difficulty of grammatical morphemes and syntactic relations. Even more problematic than verbs are "grammatical morphemes":

"Grammatical difficulties are one of the most striking features in the expressive language of many children with SLI ... Typically one sees omission of grammatical inflections ..." (Bishop, 1997, p. 116). Disruption of temporal markers on verbs is particularly extreme: "... serious problems with tense and agreement can persist through the school years and even into adulthood" (Leonard, 1998, p. 223). In a study by Moore and Johnston (1993), children with SLI were found to be more delayed in their use of temporal inflections such as past tense than temporal adverbials such as *yesterday*, *last night*, *ago*: "In essence, the SLI children were more like the 3-year-olds in their morphological performance and more like the 4-year-olds in their lexical performance" (Moore & Johnston, 1993, p. 525). This disproportionate difficulty with phonologically weak temporal terms is again in keeping with the predictions of the phonological theory.

However, the persistence of such difficulties also lies behind certain current theories which attribute SLI to specific grammatical deficits. Gopnik and Crago (1991), for example, explain difficulties with tense and number in terms of "a selective impairment of that component of grammar that encodes abstract morphology" (p. 47). As a result of the inability to acquire "particular abstract morphological rules", forms inflected for tense and number can only be acquired lexically. In similar vein, Goad (1998) proposes that SLI grammar lacks certain sublexical features, such as [+plural], so that plural forms can only be acquired as compound forms in which the plural is a stem, or as unanalysed chunks.

The Extended Optional Infinitive hypothesis proposed by Rice, Wexler, and Cleave (1995) represents another grammatical account of problems with tense marking. According to this hypothesis, the normal Optional Infinitive stage is prolonged, and possibly even permanent, in children with SLI. One of the arguments for this account is that it provides an explanation not only for omission of tense, but for omission of *be* and *do* which serve only to carry tense. It is also claimed to account for the finding that tensed forms are not used incorrectly.

These grammatical accounts of SLI are motivated by and consistent with observed difficulties with grammatical morphology. In some cases, they predict patterns of difficulty which are substantiated by the data. But they have nothing to say about the many other linguistic difficulties and patterns in these difficulties which are typically observed in SLI. As others have pointed out (Ingham, Fletcher, Schelleter, & Sinka, 1998; Van der Lely, 1998), SLI is not confined to problems with sublexical features.

Van der Lely provides a grammatical account which does address the wider problems (Van der Lely, 1998; Van der Lely & Stollwerck, 1997). According to the Representational Deficit for Dependent Relationships (RDDR) which she proposes, children with "Grammatical SLI" have "a deficit with building nonelementary, complex dependencies" (p. 178)

which lies in the syntactic computational system. The RDDR offers a unified explanation for the apparently disparate morphological and syntactic deficits which characterise Grammatical SLI. These include problems with tense marking, thematic role assignment, anaphoric and pronominal reference, wh-movement, and embedded structures. Since all these aspects of language are argued to involve complex dependencies, all are predicted to pose problems. Van der Lely works through each aspect accounting for the patterns of optional but correct marking of morphological distinctions; problems assigning thematic roles to arguments with novel verbs and to arguments in non-canonical sentence structures; incorrect and correct interpretation of anaphors; optional movement of wh; difficulties with object wh-questions and tense marking in wh-questions; limited elaboration of phrase structure. Ingham et al. (1998) put a similar case for problems with VPs which contain a resultative predication as a complement of the verb. The commonality between these apparently distinct structures is surely significant.

However, the phonological theory provides an alternative interpretation of this commonality. Ingham et al. hint at this when they allude to a ''simpler encoding of the form-meaning relation'' (p. 105) in accounting for preferred structures in SLI. The point is that long-distance or complex dependencies are characterised by just the features which the phonological theory predicted to be challenging for children with SLI:

(i) They do not relate directly to non-verbal experience: they mark functions such as timing of events (tense), perspective on events (argument structure of verbs), alternative perspective on events (non-canonical organisation of arguments); co-reference (pronouns and reflexives). They are therefore dependent on phonology to trigger the ''search'' for the semantic-syntactic contexts in which they occur.

(ii) Their phonology is demanding. Some are unstressed or sub-syllabic forms (tense, agreement); some entail phonology which extends beyond the word (verb-argument structure); some further entail relationships between elements which are phonologically separate (non-canonical structures including wh-structures).

The mapping process depends on a convergence between these phonologically challenging forms and the semantic/syntactic context in which they occur.

Patterns of error suggest that a purely grammatical account is not adequate to explain difficulties with these structures. O'Hara and Johnston (1997) provide a breakdown of errors in thematic role assignment made by children with SLI in a syntactic bootstrapping experiment. This required them to act out sentences containing novel verbs, for example:

The woman soogs the bunny
The bear gebs the boy to the woman.

O'Hara and Johnston found that 30% of the errors involved either selection of an incorrect object for one of the argument roles or omission of one of the objects, and that these selection and omission errors occurred on initial and medial NPs three times as often as on final NPs. They also note that more errors occurred on three-argument than two-argument items. They suggest that these recency and length effects point to a problem with processing load.

These conclusions are corroborated by another investigation of syntactic bootstrapping (Oetting, 1999). Presented with novel verbs in simple intransitive and transitive sentences which were embedded in a story, subjects with SLI were able to use the verb's syntactic structure as a cue to its meaning, performing no differently from age-matched or language-matched control groups. But this was only true when the child's interpretation of the verb was tested directly after presentation of the cue. When they were required to *retain* a syntactic cue until the middle or end of the story, and then interpret the verb, the scores of the children with SLI were below those of both control groups, and did not exceed chance. It looks as though, given phonologically and syntactically simple input (verbs taking a maximum of two arguments), children with SLI have little problem registering and using syntactic information as a bootstrap to a verb's meaning, but even here, they struggle to retain that information. We might predict that, if the stakes were raised by using three-place-predicates, or predicates whose syntactic frame conveys less perceptually salient information (such as event perspective), difficulties would show up even in immediate interpretation of the verb.

The conclusions from these syntactic bootstrapping tasks are supported by a study of a language-impaired child reported in Chiat (2000). The child was presented with a set of tasks designed to elicit production and repetition of verb-argument structures. His responses sometimes showed omission of verbs or arguments, or substitution with unintelligible weak forms. These omissions and substitutions occurred in tasks requiring description of acted-out and pictured events, but they were most frequent in a pure repetition task. In contrast, younger vocabulary-matched children virtually never made such omissions and substitutions, and their repetition was almost flawless. The nature of the errors made by the language-impaired child, and the fact that they were most acute in repetition, point to a problem with phonological overload which has repercussions for verb syntax.

Evaluation of a phonological account for other structures highlighted by Van der Lely awaits analysis of each in terms of the mapping processes

entailed in their growth. The motivation for pursuing this line of inquiry is that the phonological theory embraces the wider pattern of impairment which is not addressed by the RDDR. The predicted effects of disruptions in phonological processing mesh tightly with the observed range and hierarchy of difficulties with words, morphological structure, and syntactic structure. The RDDR may be equally compatible with the range of syntactic and morphological difficulties observed, but does not predict their hierarchy. A further advantage of the phonological theory, identified above, is that it predicts difficulties with phonology which the RDDR does not. This advantage is reinforced by Norbury et al.'s finding that their SLI group's performance on the Children's Test of Non-word Repetition was not only poor, but was significantly correlated with performance on a range of syntactic and morphological tasks. It was also found that performance on tests of syntactic structures implicated in the RDDR was not as consistent as the RDDR would predict. Norbury et al. suggest that these findings are more compatible with a ''non-modular account that stresses processing limitations'' than with the RDDR, and propose that ''the relationship of phonological memory and processing skills to syntactic comprehension requires further investigation''. This conclusion accords closely with the phonological theory of SLI developed in this paper, and with the final evidence to be advanced in its support: the observation that grammatical difficulties are subject to phonological factors.

Effects of phonological factors on grammatical difficulties.   If problems with function morphemes were purely grammatical, we would not expect these to be influenced by phonological characteristics, yet they are. Following on from Gerken's findings with normally developing children, McGregor and Leonard (1994) predicted that omission of function words by children with SLI would be influenced by phonological factors, but not by their grammatical category. They compared imitation of two categories (pronouns *you* and *he* and article *the*) in phonological phrase-initial position, where they preceded a strong syllable:

the GIRL KISSED him / you BOTH KISSED him,

and phonological phrase-internal position, where they followed a strong syllable:

JEFF BUMPED the CAT / JEFF BUMPED you BOTH.

Their prediction was borne out by the data. Subjects with SLI made significantly more omissions than MLU-matched controls, but the *pattern* of their omissions was the same, showing the influence of stress pattern rather than syntactic category. Both subject groups omitted pronouns and articles more frequently in phonological phrase-initial position than in

phonological phrase-internal position, but showed no difference between the two types of functions words. McGregor and Leonard conclude that ''Complexity at the phonological level resulted in deficient use at the morpho-syntactic level'' (p. 177).

The effects of phonological differences within a language are mirrored by the effects of phonological differences between languages. Extensive cross-linguistic research by Leonard and colleagues has revealed that particular grammatical categories are more affected in some languages than others (see Leonard, 1998). For example, Hebrew-speaking and Italian-speaking children with SLI do not show the disproportionate difficulty with tense marking which is observed in their English-speaking counterparts. It seems that the phonological or phonetic properties of the grammatical category are responsible for these cross-linguistic differences. The same grammatical category is easier in a language where it is stressed or post-stress, syllabic, and therefore of longer duration, than a language where it is pre-stress or sub-syllabic, and therefore of shorter duration. These findings led Leonard to propose his ''surface account'' which attributes problems with grammatical morphemes to their phonetic properties, particularly their relatively short duration. An alternative view is that these factors reflect the cues children use to segment and store morphological units, and constraints on the phonological segmentation and/or storage process in children with SLI.

Difficulties in thinking. The evidence of studies presented so far has proved highly consistent with the profile of difficulties predicted by the phonological theory. But that profile was not confined to phonological, lexical, and grammatical difficulties. The importance of phonological and syntactic packaging of meaning for the structuring of thought led to the further prediction that impairments in language development would affect the development of thought. This appears at odds with the very definition of SLI: for a diagnosis of SLI, children must show normal performance on non-verbal tests of intelligence, which implies that thinking in children with SLI will be normal as long as it does not demand language which they do not possess.

But this criterion of normal IQ in any case presents something of a conundrum. According to Johnston (1992), ''Children with specific language impairment are, by definition, children for whom the development of language and thought is out of phase'' (p. 105), yet ''Research over the past decade has revealed that children with specific language impairment do, in fact, show cognitive delays and deficits across a considerable range of tasks'' (p. 113). Informal clinical observation suggests that children with SLI often misunderstand situations, are pragmatically inappropriate, and socially awkward, despite intellectual

and social problems figuring among the exclusion criteria. Yet they are also felt to be ''normal'' socially and emotionally, despite their sometimes odd pragmatic and social behaviour.

Investigations by Johnston and her colleagues have exposed cognitive differences between children with SLI and normally developing children which cannot be attributed to differences in their language. In an experiment reported by Johnston, Smith, and Box (1997), a group of SLI children (with IQ in the average or superior range) and a group of normally developing controls were presented with a referential task requiring them to identify two objects from an array of three. The two objects shared size or colour or whole identity with each other, but not with the third object. The most sophisticated way to identify the targets is by means of a "Quantitative Grouping strategy''. This requires the abstraction of the dimension or identity shared by the targets, permitting reference to them as a set: "the green ones'' or "the big ones'' or "the trees''. Alternative strategies include, for example, use of deictics ("this one and that one''), and exhaustive description of each object ("a green big one and a green little one''). The striking finding was that the children with SLI were as successful as the controls in identifying the target objects, but they were less likely to use the Quantitative Grouping strategy to do so. Their reduced use of this strategy could not be attributed to their linguistic deficit, since they demonstrated knowledge of the required terms for virtually all items. Johnston et al. suggest that it is cognitive load that distinguishes the Quantitative Grouping strategy. By inference, the reason this strategy is particularly challenging for children with SLI is that they have reduced cognitive resources. The nature of their capacity limitation, Johnston et al. acknowledge, remains uncertain.

An appeal to Slobin's notion of ''thinking for speaking'' may offer a way forward. ''Thinking for speaking'' is not co-terminous with thinking in general. It refers to the structuring of mental representations in ways which are required by language, rather than to all forms of mental representation. Differentiation between ''thinking for speaking'' and other sorts of thinking may provide a basis for explaining the apparent paradox of children being diagnosed with *specific* language impairment, by exclusion of intellectual disturbance, yet showing limitations which cannot be directly attributed to language, such as those observed by Johnston et al. If ''thinking for speaking'' is required only for certain thought processes, disruptions in ''thinking for speaking'' could plausibly give rise to cognitive problems such as those we have observed, while sparing other thought processes such as those engaged by typical IQ tests. The resulting cognitive impairments may in turn affect some aspects of pragmatic and social development, yet spare others such as the development of emotional attachment and the construction of self and other. Detailed evaluation of

these possibilities awaits more precise formulation of "thinking for speaking", allowing more precise hypotheses about thinking in SLI and its repercussions.

Ultimately, an understanding of "thinking for speaking" may enable us to clarify differences between children who *are* experienced as pragmatically "odd", and others who present with pragmatic behaviours which are odd, yet are experienced as "pragmatically normal"—in the terms of Bishop et al. (2000), children with Pragmatic Language Impairment (PLI) and children with SLI-Typical. Perhaps the SLI-Typical group have a deficit in "thinking for speaking", i.e., in the organisation of meaning entailed in linguistic representation, while the PLI group have a deficit in the interpretation of non-verbal experience itself. Behaviours resulting from these deficits may look similar and make differential diagnosis very tricky. The lived experience of the deficits, and at least some of their observable effects are surely quite distinct (see, for example, Bishop et al., 2000).

THE CASE SO FAR: EVIDENCE, IMPLICATIONS, PREDICTIONS, QUESTIONS

This paper set out with a logical argument that the acquisition of language is fundamentally a mapping process, and that constraints on this mapping process are the most plausible source of limitations in language acquisition. The logical case was substantiated with detailed evidence of what is entailed in the mapping process which highlighted the role of complex phonological processing in lexical and syntactic development. The phonological theory of SLI is rooted in these observations about the mapping process.

The predicted effects of a phonological deficit on the child's language were highly consistent with wide-ranging research findings on SLI. This favours the phonological theory over theories which address selected linguistic features and say little about observed difficulties which fall outside their scope. Theories postulating specific grammatical deficits, for example, offer no account for the complex patterns of problems in grammatical morphology and syntactic structure, and for problems observed in other domains. They are particularly hard pressed to account for evidence that children with SLI have independent difficulties with phonology, and for correlations that have been found between some measures of phonological and grammatical deficits. Such evidence challenges even a broad-range syntactic theory of SLI such as the RDDR.

It does not, however, rule out the possibility of a dissociation between these phonological and grammatical difficulties. Conclusive evidence of such a dissociation would undermine the phonological theory, since this

identifies phonological difficulties as the source, rather than a typical concomitant, of grammatical difficulties. The phonological theory predicts that children alleged to have a purely grammatical deficit will manifest problems with phonology in tasks which demand fully intact phonological processing, for example in non-word repetition and ''fast mapping'' tasks. Conversely, it predicts that children alleged to have purely phonological difficulties in segmenting and storing words will manifest problems in tasks which demand high-level syntactic skills. The case for the phonological theory would be strengthened by evidence which, in line with these predictions, refuted alleged dissociations.

The novelty of the proposed phonological theory lies in the *specific* connections it makes between deficits in phonological processing and deficits in lexical and syntactic development. This differentiates it from a processing theory which attributes SLI to a general limitation in processing capacity. Studies which invoke a limited processing capacity rarely map out the path from the hypothesised limitation to the particular range of deficits observed in SLI. In contrast, the phonological theory proposed in this paper targets the *whole pattern of impairment*, and provides an account for many of the findings which have emerged from diverse studies of groups and individuals meeting the standard criteria for SLI.

This construal of SLI has significant implications for further research. The hypothesis that phonological processing is the problem leads to further questions about the nature of that problem and its ramifications. Some of these questions were anticipated in the initial formulation of the hypothesis. For example, is the difficulty with phonology due to more fundamental difficulties with temporal integration of acoustic information and possibly any rapid temporal integration (as in Tallal et al., 1998), or are these independent or otherwise related impairments? Findings that peripheral auditory processing problems are not sufficient to account for problems in the representation and production of lexical phonology in at least some children with SLI (Chiat & Hunt, 1993; Constable et al., 1997) point in the direction of a more extensive deficit affecting central and output phonological processing. However, this may vary between children. Do some children show problems which can be wholly attributed to peripheral input or output processing or to central processing, or does SLI entail deficits at all stages of phonological processing and if so, are these deficits interrelated? What is the nature of the hypothesised deficit in phonology? Does it affect prosodic structure itself, or is it confined to segmental details within the prosodic structure? Are some aspects of prosodic or segmental phonology more vulnerable than others? Do children show differences in the aspects of phonology affected and/or the degree of those effects, and do these correlate with other aspects of the child's language?

Predicted effects on semantic and syntactic development invite further investigation. Current evidence is too sparse to evaluate predicted strengths and weaknesses in the semantics and syntax of verbs. In order to determine, for example, whether components of verb meaning which correlate directly with non-verbal experience (for example mental state) are easier than those which do not (for example perspective on transactions) we will need to investigate comprehension and production of different types of verbs in carefully controlled contexts. Syntactic and semantic bootstrapping tasks could yield further insights if they employed verbs and verb frames associated with different types of events. Of particular interest would be those events which can be viewed from different perspectives, for example events of the give/take and fill/pour variety, where either the specific focus in the scene or the syntactic frame is crucial in determining the verb's perspective on the event.

The focus of this paper has been the hypothesised deficit in phonological processing and its effects on the mapping process in SLI. The wider mapping theory which introduced the paper predicts that other types of language impairment may occur as a result of deficits at other points in the mapping process. Allusion was made to the possibility that deficits in the interpretation of non-verbal experience, and hence in the interpretation of scenes, may lie at the root of Pragmatic Language Impairment. The analysis of the mapping process leads to predictions regarding the effects of disruption at this point in the mapping process. One such prediction is that children with PLI, unlike those with SLI, will have a normal capacity for phonological processing and will perform normally on purely phonological tasks even where the demands of the task are high, as in non-word repetition (though difficulties in understanding or co-operating in the task could be an obstacle to obtaining evidence). This in turn predicts that children should have the phonological wherewithal to segment and store phonological units. The hypothesis that the deficit arises in the interpretation of experience leads to questions about the aspects of experience which are limited or impaired; the range and severity of impairment in different children; the effects on the meanings which they attach to lexical and syntactic forms; and the relationship between the resulting deficits in linguistic meaning and deficits in pragmatic interaction.

The phonological theory of SLI and the wider mapping theory proposed in this paper have generated a range of further hypotheses and questions, some highly specified, some inviting tighter specification. These point towards further research which might give us better insights into the experience of language-impaired children and their potential: the kinds of thoughts they can think and the kinds of language into which they can put thoughts. The theories developed in this paper also open up new directions for research into intervention. The better we understand the connections

between components of the mapping process, the better we can anticipate the benefits and limitations of interventions in the mapping process. For example, suppose that manipulation of auditory input is found to be effective, as suggested by Tallal et al. (1998). The mapping theory makes predictions about how such intervention will affect particular aspects of lexical and syntactic structure. Understanding these effects may influence selection of linguistic material to be targeted in such a programme.

This paper has presented a logical and empirical case for a mapping theory of developmental language impairment and its offspring phonological theory of SLI. It concludes with a different motivation for the proposed theories: their potential as a catalyst for research which is of theoretical interest and practical consequence.

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