Bootstrapping mechanisms in first language acquisition

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Abstract

In the field of language acquisition the term bootstrapping stands for the assumption that the child is genetically equipped with a specific program to get the process of language acquisition started. Originally set within the principles and parameters *framework bootstrapping mechanism are considered as a linkage between properties of the specific language the child is exposed to and pre-existing linguistic knowledge provided by* universal grammar. *In a different view — primarily developed within the so-called* prosodic bootstrapping account — *bootstrapping mechanism direct the child's processing of the input thereby constraining the child's learning in a linguistically relevant way. Thus, the attendance to specific input cues provides the child with information to segment the input in linguistically relevant units which constitute restricted domains for more general learning mechanism like e.g., distributional learning. The paper will present a review of empirical findings that show that children are in fact equipped with highly sensitive and efficient mechanism to process their speech input which initially seem to be biased to prosodic information. It will be argued that further research within this framework has to deal with the reliability of the proposed relevant input cues despite crosslinguistic variation and with children's ability to overcome an initial reliance on single cues in favor of an integration of different sources of information.*

1. Introduction

In the field of language acquisition, there is no doubt that both cognitive mechanisms inherent to the child — either innate or subject to development themselves — as well as adequate linguistic input are necessary conditions for the child to acquire language. But even after decades of intensive research in language acquisition, our understanding of how these

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essential components interact to produce a full competence of the native language is still fragmentary.

In this chapter I will try to give an overview of the state of the art of empirical findings and theoretical considerations within so-called Bootstrapping Approaches. Literally, a bootstrap is a small strap on the back of a leather boot that serves as an aid to pull the entire boot on. Metaphorically, this term was first used in computer science. There, *to bootstrap* or *to boot* means to load the operating system of a computer by first starting a smaller initial program (bootstrap loader). On early computers the bootstrap loader was very short and just had the function of reading in a more complex program which in turn loaded the operating system from an external drive. In general usage, bootstrapping is the leveraging of a small initial effort into something larger and more significant (http://searchsmb.techtarget.com; http://www.instantweb.com).

The term *bootstrapping* was introduced into the field of language acquisition by Pinker (1984) as a metaphor for the assumption that the child is genetically equipped with a specific program to get the process of language acquisition started. Bootstrapping accounts of language acquisition stress the interaction of speech input with the process of language acquisition, trying to identify learning mechanisms that help the child to learn about structural properties of the native language with the aid of input features. I will try to examine which kinds of acquisitional problems these approaches may provide solutions for, how realistic the assumptions about infants' speech processing skills made by these accounts are and which kind of empirical evidence supports these assumptions. Due to the richness of the work done within this framework, the Prosodic Bootstrapping Account will be at the focus of the chapter.

2. The underlying concept of learning

2.1. *Basic assumptions of bootstrapping accounts*

One of the central questions in language acquisition is how the child is able to break into the system of the specific language she is going to learn. Pinker (1984, 1987) was the first to explicitly discuss this bootstrapping problem as a fundamental problem for the language learner and for models of language acquisition resulting from a discrepancy between the input and the output of language learning:

> The input to the child consists of sentences heard in context. If we are charitable about the child's perceptual abilities, we can assume that he or she can extract a variety of types of information from the input: the set of words contained in the

> sentence; their order; prosodic properties, such as intonation, stress, and timing; the meanings of individual content words, insofar as they can be acquired before grammar learning begins; crude phonological properties of words, such as the number of syllables; the semantics of the utterance inferred from the nonlinguistic context, including its predicate-argument structure and relations of coreference and predication; and finally, pragmatic information inferred from the discourse context, such as topic versus focus. The output of language learning is a rule system of the adult language. This rule system, or grammar, consists of rules, principles, and parameter settings couched in a formal vocabulary, including syntactic categories (nouns, verb, etc.), grammatical relations and cases (subject, object, oblique object, nominative, accusative, etc.), and phrase structure configurations (''daughter of'', ''sister of'', ''precedes''). (...) The problem is that there is no direct relation between the types of information in the input and the types of information in the output: tokens of grammatical symbols are not perceptually marked as such in parental sentences or their contexts. (Pinker 1987: 398–399)

Pinker's solution for this problem is embedded into the Principles and Parameters Account (e.g. Atkinson 1992; Chomsky 1981, 1986, 1999; see also Eisenbeiß this issue): equipped with innate universal constraints on grammar, the child's task is to find the language specific instantiations of universal categories and the specific settings in domains of parametric variation. This matching between language specific properties and the grammatical system given by UG cannot be achieved by purely perceptual mechanisms since — as stated above — there are no perceptual markers of linguistic categories and rules in the child's speech input. Bootstrapping mechanisms are assumed to specifically fill this gap: they provide a linkage between input properties and knowledge of linguistic entities like ''noun'' or ''subject of'' provided by UG. This linkage itself is assumed to be part of an innate domain-specific inventory of capacities the child brings to the task of language learning.

This concept of bootstrapping underlies various proposals for bootstrapping mechanisms that are described in more detail below: semantic bootstrapping (Pinker 1984; 1987), syntactic bootstrapping (Gleitman 1990) and the rhythmic activation principle for setting the head direction parameter (Nespor et al. 1996).

A second set of bootstrapping approaches is more focused on the information the child can directly access from her input. According to Pinker's theory, the child's input already contains linguistic units and categories of different sorts: sentences, words, syllables, etc. But acoustic phonetics and speech perception research have shown that the speech signal consists of nothing more than a string of acoustic events that only through subsequent linguistic interpretation emerges as a sequence of words and sentences. One of the central questions in research on speech and language processing is how this linguistic interpretation of the signal works, i.e., how the listener can match the acoustic string or parts of the acoustic string to a representation in her mental lexicon or how she can assign a specific syntactic structure to the incoming speech signal. Since the signal itself does not provide any unique acoustic cues to its underlying linguistic structure, it is assumed that the linguistic interpretation of the signal requires the listener to use her linguistic knowledge (e.g., McQueen 1998; Soto-Faraco et al. 2001; Frazier and Clifton 1996).

If so, the child is in a dilemma: she has to analyze the linguistic input to discover the language specific, e.g., syntactic and lexical, properties of the target language. But to so analyze the input, she must already have some knowledge of the target language — some understanding of its properties — thus putting the child in a circular situation. Bootstrapping approaches of this second class have focused on the question of how the child starts to analyze her input in a linguistically adequate way, essentially, how the child finds the linguistically relevant units like words, phrases, and sentences.

Within this concept, bootstrapping mechanisms thus have the role of detecting structural units and properties in the input that can serve as constraints for further learning, as, for example, Morgan and Demuth (1996) point out:

> . . . Rather, these accounts propose that information available in speech may contain clues to certain fundamental syntactic distinctions, providing additional constraints on children's syntactic and semantic analyses, signaling the domains within which such analyses may be efficiently deployed, and helping to ensure that these analyses get started in the proper direction. (Morgan and Demuth 1996: 2)

According to this view, bootstrapping mechanisms thus do not give direct access to the grammar of the language to be learned, nor is it assumed that grammar can be read off from perceptual representations in an unconstrained manner. Instead, bootstrapping mechanisms serve as a filter between input and learning to constrain the learning mechanisms in a linguistically relevant way. The learning mechanisms themselves can be of a general character like distributional learning, not necessarily being domain- and species-specific (Hauser et al. 2002; Hauser et al. 2001; Newport et al. 2004; Saffran et al. 1999).

2.2. *Variants of bootstrapping*

Several kinds of bootstrapping mechanisms that serve quite different specific functions in the complex task of language learning have been proposed. What they have in common is the idea that the child can either use cues from the speech input or knowledge already established in one linguistic domain for acquiring further linguistic knowledge either within the same domain (autonomous bootstrapping; c.f. Durieux and Gillis 2001) or within another domain (interdomain bootstrapping).

Bootstrapping mechanisms are characterized by the kind of information that serves as their input and the domain they help the child break into. In the following, the main types of bootstrapping mechanisms according to this characterization are introduced.

2.2.1. *Distributional bootstrapping.* This group of mechanisms is assumed to compute nonprosodic segmental statistical properties of the speech input on different levels of linguistic structure (phonemes, syllables, morphemes). The assumption is that patterns of frequently co-occurring elements are used as the basis for finding syntactically relevant units in the input and assigning these units to linguistic categories. For example, phonotactic regularities constrain the syllabification of the input string and thereby can help identify word boundaries (e.g., Brent and Cartwright 1996); inflectional endings and function words which typically belong to the high-frequency category and typically occur at the edges of words or syntactic phrases may provide boundary information as well as information for the syntactic categorization of the elements they occur with (e.g., Gerken 1996; Höhle et al. 2004; Maratsos and Chalkley 1980; Mintz et al. 2002; Pelzer and Höhle 2006).

There is rich evidence that from early on children are sensitive to the distributional patterns of their input. Experiments by Saffran et al. (1996) have shown that infants can compute transitional probabilities between elements of the input string after a relatively short exposure. This does not only hold in a situation with well-controlled speech input such as in experimental studies but obviously also holds for the processing of language in natural interactions: at 9 months, infants have learned about the phonotactics of their native language (Friederici and Wessels 1993; Jusczyk et al. 1993) and they can discriminate high-frequency phoneme combinations from those with a lower frequency (Jusczyk et al. 1994). This ability might help children extract first words from the input and build up lexical representations for these. The fact that by the end of their first year children do already recognize some forms of high-frequency function words in their input (Höhle and Weissenborn 2000) supports this idea.

2.2.2. *Semantic bootstrapping.* As already mentioned, Pinker's (1984) concept of semantic bootstrapping addressed the question of how the child finds instantiations of linguistic categories and relations given by UG in her target language. Semantic bootstrapping makes use of a semantic-syntax association. Semantic notions like "action" or "agent" are linked to syntactic notions like "verb" or "subject of" which are part of the UG. Pinker assumes that children can construct a rudimentary semantic representation of the input sentences with the help of context and their ability to understand the meanings of the words of the sentences. They are thus able to identify basic semantic entities like "agent" or "action", etc. With the help of innate linking rules they can connect these semantic entities to the corresponding grammatical categories, and thereby identify the specific morphosyntactic features of the syntactic categories and relations in their target language.

2.2.3. *Syntactic bootstrapping.* According to the syntactic bootstrapping approach proposed by Gleitman (1990) children use the syntactic frames in which verbs appear to decide on specific semantic components of a verb's meaning. So, for example, a verb used in a transitive context is assigned a causative reading while a verb appearing in a nontransitive context is not. In fact, there is experimental evidence that supports the idea that children make use of a verb's structural context when they have to decide between a set of alternative actions a verb might refer to (Naigles 1990).

Findings of Waxman and Booth (2001) can also be interpreted as support for some kind of syntactic bootstrapping, even though these researchers did not explicitly conduct their work within this framework. They showed that children use the syntactic context a novel word appears in to determine its meaning. If presented with a context in which an unknown word is used as a noun ("look, it's a blicket") 14-month-old babies select an object as the referent for the new word. In contrast, presented with a context in which the word is used as an adjective ("look, it's blickish") they select a property as the referent.

The same function may be carried by inflectional endings that in many cases are specific for a syntactic category. For instance, the English *-ing* ending typically signals a verb and obviously English-learning children interpret novel words carrying this ending as referring to an action (Brown 1957).

2.2.4. *Typological bootstrapping.* The concept of typological bootstrapping (Slobin 2001) focuses more strongly on crosslinguistic variation in form-function relations that challenge the assumption of innate linking rules between semantic and syntactic notions as proposed by the semantic and syntactic bootstrapping accounts. For example, in Korean motion verbs include information about the spatial relation between the moved object and its target destination that is more typically specified by a preposition in English, i.e., the Korean verb *kkita* can be translated as *put in* without showing the same extension (Bowerman and Choi 2001). Similarly, there is systematic crosslinguistic variation with respect to how path and manner of a motion are encoded (Talmy 1985). In so-called satellite-framed languages like e.g., English and German manner is typically a semantic component of the verb stem while path information is given by particles or prepositions. In contrast, in so-called verb-framed languages like Spanish or French path information is typically encoded by the verb stem while manner is given by adverbs.

Children follow these language specific form-function relations from early on (Choi and Bowerman 1991; Choi et al. 1999; Papafragou et al. 2002). Accordingly, they learn what kinds of meanings are typically expressed by which categories establishing the specific pattern of lexical and grammatical categories in the language learned. By this knowledge the child can then draw inferences about the meaning of new members of these categories.

2.2.5. *Prosodic bootstrapping.* Gleitman and Wanner (1982) were among the first researchers who pointed out that prosodic information might help the child discover the underlying grammatical organization of the native language. This assumption, i.e., that prosodic cues like stress, rhythm and intonation help the child segment the speech input into linguistically relevant units and categorize these units syntactically, underlies much work in acquisition research (for a review see Jusczyk 1997). It has been further proposed that prosodic information from the input can help identify word order regularities in the native language. The Prosodic Bootstrapping Account is discussed in more detail in the following chapters.

3. Applications of the concept of bootstrapping

3.1. *Prosodic bootstrapping of word order*

The *rhythmic activation principle* proposed by Nespor and colleagues (Nespor et al. 1996; Guasti et al. 2001) focuses on how children can make use of prosodic information to acquire the basic word order rules of their language. Embedded in the parameter setting approach to language acquisition (Chomsky 1981, 1986, 1999) is the assumption that the acquisition of language specific word order rules involves the setting of the head-direction parameter. Nespor and colleagues argue that children can set this parameter with the aid of information about the rhythmic properties of the target language. This bootstrapping mechanism uses a correlation that holds between the order of the head and its complement within a syntactic phrase and the position of the prosodic prominence within a phonological phrase. Typically, phonological phrases in head-initial languages assign stress to elements at the right edge of the phrase while phonological phrases of head-final languages have their prosodically most prominent element at the left edge of the phrase. This leads to different rhythmic patterns within the intonational phrase in these languages. In head-initial languages like French and Italian the intonational phrase typically shows a weak-strong pattern, while in head-final languages the pattern is strong-weak. Nespor and her colleagues propose that children can make use of this correlation by an innate principle they call the rhythmic activation principle:

> When you hear sequences of (ws)* within an intonational phrase, set the head complement parameter with the value head complement. When you hear sequences of (sw)* within an intonational phrase, set the head complement parameter with the value complement head. (Guasti et al. 2001: 237)

There is empirical evidence that children have the perceptual capacities necessary to use the rhythmic activation principle. Christophe et al. (2003) have shown that infants are able to discriminate speech stimuli from a head-complement language like French from a complement-head language like Turkish from birth on, even if these stimuli are identical with respect to their segmental structure. Findings from our lab suggest that 18-month-old infants learning German do discriminate between sentences with correct verb placement and sentences with ungrammatical verb placement if there are clear prosodic differences between the two types of sentences (Höhle et al. 2001b). But more direct evidence that children actually use the correlation between rhythmic properties and the head direction of a language to acquire word order regularities is still missing.

3.2. *Prosodic bootstrapping of phrase and clause boundaries*

As mentioned above the majority of work within the framework of Prosodic Bootstrapping follows the idea that prosodic information might help the child identify units in the speech stream that correspond to syntactic or lexical units in the language, thereby providing structural units that are linguistically relevant and which may help constrain hypothesis on the structural principles underlying the utterances (e.g., Jusczyk 1997; Morgan 1986; Morgan and Demuth 1996). This research has investigated three main questions: First, is there a systematic relationship between properties of the input and linguistic structure? Second, is the child sensitive to or does she have knowledge of the property that functions as the source of the bootstrapping mechanism? Third, does the child use the cues or the already established knowledge in the assumed way?

Since the seminal work of Cooper and Paccia-Cooper (1980), the fact that in many utterances syntactic boundaries are marked by prosodic boundary markings is well accepted. Among the acoustic cues that can mark prosodic boundaries are the lengthening of the final syllable preceding the boundary, pitch movements preceding the boundary and pausing at the boundary. This kind of information is integrated into the parsing of the syntactic structure of an utterance by adult listeners — leading for example to the resolution of local and global syntactic ambiguities (for a review see Cutler et al. 1997). From a prosodic point of view these boundary cues mark the edges of intonational and phonological phrases whose boundaries often correspond to the boundaries of major syntactic units such as sentences, clauses or phrases.

The currently available evidence strongly suggests that infants are sensitive to the acoustic features that serve as boundary cues from early on. Several studies have shown that infants from around 6 months on react differently to speech strings with pauses inserted at syntactic clause or phrase boundaries than to speech strings with pauses inserted within clauses or phrases (Jusczyk et al. 1992; Hirsh-Pasek et al. 1987). This behavior suggests that the children are sensitive to the disruption of the normally cohering cues in the sentences with pauses at positions not coincident with phrase boundaries. This shows that infants know about the specific acoustic features associated with boundaries and that they have the perceptual capacities to process these cues as structural markers in speech input.

In addition it has been shown that information presented within coherent prosodic units is easier for children to process than information not presented within coherent prosodic units. Mandel et al. (1994) found that infants as young as two months old are better at remembering phonetic details of words if these words were presented within prosodically well-formed sentences than when they were presented within lists of words. An analogous result was found in a further experiment that compared the reaction of infants to phonetic changes within a sentence produced as a single intonational phrase compared to a sentence not constituting a single intonational phrase.

Comparable findings are reported by several recent studies that found that 6-month-olds are better at detecting a sequence of previously heard words when this sequence appeared as a single prosodic unit in a text passage compared to a passage in which the same sequence of words appeared in two adjacent sentences or phrases and included a prosodic boundary (Nazzi et al. 2000; Seidl 2007; Soderstrom et al. 2003). Seidl et al. (2004) provide evidence that this effect is not dependent on existing knowledge of the language tested. They report that English-learning 6-month-olds were better at detecting words in a single prosodic phrase when presented with speech material from a foreign language, Dutch in this case.

3.3. *Prosodic bootstrapping of word segmentation*

A further area directly associated with the term prosodic bootstrapping relates to the question of how children start to segment their input into smaller units than clauses and phrases, namely, words. In contrast to the cues discussed as signals to clause and phrase boundaries, there are no clear acoustic-phonetic cues associated to word boundaries (e.g., Cutler 1994). The segmentation processes used by adult listeners are obviously shaped by the rhythmic properties of their native language. The syllable seems to be the basic unit of segmentation for speakers of French, Spanish, Catalan, and Portuguese (Cutler et al. 1986; Sebastián-Gallés et al. 1992; Morais et al. 1986). In contrast, speakers of English, Dutch, and German rely on the stress pattern by segmenting the input into trochaic feet (Cutler et al., 1986; Vroomen et al. 1996; Höhle and Schriefers 1995) while speakers of Japanese seem to rely on the mora as the basic unit of segmentation (Otake et al. 1993). These processing differences coincide with a typological classification of languages on the basis of their rhythmical properties (Abercrombie 1967; Pike 1945). According to this classification the rhythmical pattern of most Germanic languages like English, German, or Dutch is based on the stress unit, i.e., the foot (stress-time languages), most Romance languages (e.g., French, Italian, Spanish) show a rhythmical pattern based on the syllable (syllable-timed languages), and languages such as Japanese show a mora-based rhythm (mora-timed languages). This suggests that the listener uses the basic rhythmical unit of the native language as the fundamental unit for segmentation.

Nazzi and Ramus (2003) have proposed that the emergence of this segmentation procedure must be based on the infant's ability to specify the type of rhythm of the native language. This provides the learner with information about the basic metrical unit of the native language from which the appropriate segmentation strategy can be developed. Thus, infants learning a stress-timed language should start with the foot as the basic unit for segmentation, while children learning a syllable-timed language should start with a syllable-based segmentation strategy and Japanese learning children with a mora-based procedure.

To validate this proposal we have to again ask which acoustic correlates to the rhythmic classes might allow the child to specify the rhythmic type of the native language. As mentioned before, the traditional typological classification of different rhythm classes is based on the assumption that languages differ with respect to the basic rhythmical unit. Those units that bear the rhythm should appear in constant intervals and therefore be similar with respect to their duration (Pike 1945). Thus for example, single feet should be comparable in duration in stress-timed languages while single syllables should be comparable in duration in syllable-timed languages. However, phonetic analyses have not provided any evidence for this hypothesis. The duration of feet in stress-timed languages is highly variable and increases with the number of constituent syllables (e.g., Dauer 1983; Lehiste 1977). In addition, stress-timed and syllable-timed languages are comparable with respect to their variation in the duration of single syllables depending on the complexity of the syllables and their position within an utterance (e.g., Delattre, 1966).

Ramus et al. (1999) investigated another basis for rhythmic distinction. They hypothesized that the rhythmic classification correlates with the complexity and the variety of syllabic structures that are allowed in languages. Their analysis, which took into consideration the percentage of vocalic parts of the utterances and the variability of duration of the consonantal parts, grouped the languages exactly as predicted by the classical typological grouping: English, Dutch, and Polish formed one cluster with the lowest percentage of vocalic parts and the highest variability in consonantal parts. Spanish, Italian, French, and Catalan formed a second cluster with a higher vowel proportion and a lower degree of variability in consonantal parts. Japanese stood apart from the other languages analyzed with the highest proportion of vocalic parts and the smallest degree of consonantal variability.

The question of whether infants are sensitive to the rhythmic organization of language has been mainly tested by infants' ability to discriminate different languages. Nazzi et al. (1998) as well as Ramus and coworkers (Ramus et al. 2000; Ramus 2002) showed that French newborns can discriminate languages not belonging to the same rhythmic classes (e.g., English and Dutch from Japanese or Italian) but that they fail with languages belonging to the same rhythmic class (e.g., English from Dutch or Italian from Spanish). These results were obtained with speech material in which segmental contrasts were eliminated either by low-pass filtering or by replacing all segments by identical vowels or consonants. In contrast, discrimination was only possible if the stimuli were played forwards but not when played backwards. This supports the assumption that the basis for discriminating the languages was in fact the prosodic and not the segmental properties of the speech stimuli.

These findings are thus strong evidence that infants are equipped with perceptual mechanisms that are particularly sensitive to the rhythmic-prosodic properties of languages and allow them to identify the rhythmic properties of speech from birth on. In addition, several studies have shown that infants' segmentation and "packaging" of their speech input into wordlike units is guided by rhythmic information from early on (e.g., Echols et al. 1997; Morgan 1996; Morgan and Saffran 1995). The most direct evidence that these capacities are closely related to the emergence of word segmentation skills stems from work by Jusczyk et al. (1999). In a series of studies they showed that 7.5-month-old infants learning American were able to segment trochaic words out of continuous speech but that they failed with iambic words. In addition the infants seemed to detect a syllable in a text passage which they had been familiarized to as the strong syllable of an iambic word at the beginning of the experiment. This finding could not be replicated for syllables that had been the strong syllable of a trochaic word during the familiarization. This suggests that the trochaic words were represented as single units by the infants whereas the iambic words were split into two separate parts. At the age of 10.5 months the infants did not show these different reactions to trochaic and iambic words anymore. German or Dutch learning 9-month-olds show similar patterns of segmenting trochaic words (Höhle et al. 2001a; Houston et al. 2000). These results suggest that infants learning a stress-timed language like English, Dutch or German start with a segmentation strategy that is metrically driven, treating a sequence of a strong and a following weak syllable as a unit.

Further support that the early segmentation skills are a function of the rhythmic properties of the target language is provided by studies with infants learning French (Nazzi et al. 2006). French children seem to start segmenting their input on the basis of single syllables: 12-month-olds failed to detect whole bisyllabic words in continuous speech but reacted to the isolated syllables of the bisyllabic words. Only with 16 months bisyllabic words are segmented as whole units by French learners.

These crosslinguistic findings suggest that rhythmic information is a general cue for the development of infants' word segmentation skills that seem to be shaped by the language specific input properties the child is exposed to from early on probably even influenced by dialectal variation or conditions of multilingual input (Polka and Sundara 2003). More crosslinguistic research will be necessary to get a clearer picture of how specific properties of the target language and infants' perceptual capacities interact in developing segmentation procedures that are adequate for the native language.

4. Strengths and weaknesses of the concept of bootstrapping

Bootstrapping accounts make very clear predictions about the kind of information the child might use for the solution of a specific task within the language learning process. With the development of suitable experimental methods such as habituation and conditioning tasks, these predictions can be now tested empirically from birth on or even before. Indeed, the concept of bootstrapping has instigated an enormous number of empirical studies during the last twenty years that focus on the perceptual capacities children bring to the task of language learning and the availability of proposed bootstrapping mechanisms from the earliest age on (for a review see Jusczyk 1997). The results of this empirical work have changed our understanding of the language learning child dramatically: we now know that the acquisition of specific properties of the input language starts with birth and probably even before (DeCasper and Spence 1984), and that the first two years of life are an extremely important period for the acquisition of phonological and morphosyntactic knowledge. The possibility that learning begins before birth might especially require another "rethinking of innateness".

Bootstrapping accounts provide a natural explanation for areas of seemingly error-free acquisition. This holds especially for those accounts formulated within the framework of UG. If a parameter is set by the identification of specific input patterns, the corresponding linguistic knowledge is established as soon as the child has the perceptual capacities at her disposal and has identified the necessary input features. This can happen long before the child is able to produce utterances that indicate that a specific grammatical property has been acquired, as shown for instance in the domain of the acquisition of word order regularities (Höhle et al. 2001b).

Bootstrapping accounts postulate interfaces between different domains or modules of the language system or between subcomponents of a domain. These interfaces may be responsible for parallel acquisition in different domains of language. For instance, Bates and Goodman (1997) point out a correlation between vocabulary growth and increasing syntactic complexity across languages and across such different groups as normally developing children, late talkers, children with brain lesions and children with genetic syndromes. Bates and Goodman propose a non-modular interpretation for this correlation, i.e., in their view, grammar and lexicon are inseparable and are handled by the same processing and learning mechanisms. But they concede that the observed association could be a product of bootstrapping. For instance, for syntactic bootstrapping to work adequately, the child must be able to use different syntactic aspects of utterances including word order and morphosyntactic markers. Delayed abilities in this area would result in a decreased efficiency in learning new words. Thus, correlations between skills can be explained without abandoning the concept of modularity.

The same line of argument holds in the search for causal factors of developmental language impairments. It has been suggested that children with specific language impairments show reduced bootstrapping capacities (O'Hara and Johnston 1997; Penner and Kölliker-Funk 1998; van der Lely 1994). Causal linkages between different problems shown by SLI children can thus be established. For instance, there is evidence that many SLI children do not process prosodic information adequately (Weinert 1996). In addition, for many German-learning SLI children the acquisition of the V2-rule poses a specific problem (Hamann et al. 1998). At first glance, these two phenomena seem to point to two different impairments: one that would be attributed to the phonological domain and a second that would be attributed to the syntactic domain. But the rhythmic activation principle as described above (Guasti et al. 2001) suggests that an impairment of the processing of prosodic information should affect children's abilities in acquiring word order regularities. Thus, the bootstrapping account opens new perspectives for research on SLI.

Besides these strengths of the bootstrapping concept, some weaknesses should be mentioned. One major point of concern is whether the bootstrapping mechanisms proposed so far are really useful as a starting point into penetrating the language system, i.e., is there a single mechanism that works without already existing linguistic knowledge about the specific system to be acquired and are those cues proposed as input for the bootstrapping mechanism reliable?

First, to work without existing linguistic knowledge, bootstrapping mechanisms are restricted to relying on information that is not affected by crosslinguistic variation. But even acoustic cues that are associated with the boundaries of phonological phrases seem to vary between different languages (Venditti et al. 1996). A further problem is the fact that units of different linguistic domains are not isomorphous. The prosodic phrasing of an utterance is not a direct reflection of syntactic structure but is influenced by aspects of the informational structure (Selkirk 1984) as well as by performance factors as e.g., the length of the whole utterance or of single constituents and the speech tempo (Ferreira 1993; Grosjean et al. 1979). This means that utterances with the same syntactic structure can vary with respect to their prosodic structure. In addition, there are systematic discrepancies between the prosodic and the syntactic structure in cases when a syntactic phrase consists only of a pronoun that does not carry contrastive stress (Gerken et al. 1994; Selkirk 1996). However, infant-directed speech seems to be more consistent with respect to the syntax-prosody correlation than adult-directed speech (Fernald and Simon 1984; Fisher and Tokura 1996) making this register a particularly reliable input for bootstrapping mechanisms.

A further matter of consideration is the reliability of the individual acoustic cues that serve as boundary markers. All these acoustic cues, taken alone, serve quite different functions within the linguistic system (Fernald and McRoberts 1996). For example, F0-contours are associated with pragmatic functions like signaling whether an utterance is meant as a question or as an assertion. Lengthening is a relational property that can only be computed in comparison to the same syllable not produced phrase finally. The absolute duration of a single segment does not give any information concerning lengthening as segments differ with respect to their inherent duration, whether they appear in a stressed or an unstressed syllable and whether the language makes use of length as a phonologically distinctive feature. Pausing is not only related to boundaries but can also be an indication of some problem in the production process such as, for instance, problems in lexical access. Given these reasons, Fernald and McRoberts rate the reliability of these acoustic cues as boundary markers as quite low and overestimated.

As pointed out earlier, most bootstrapping mechanisms can only make an initial guess about the possible categories and units of the input. Due to the fact that units in different linguistic domains do not map onto each other in a one-to-one fashion but only show a more or less close correlation, the child has to overcome the application of a bootstrapping mechanism at some point during development.

That is, for instance, if the child kept relying exclusively on a metrical word segmentation strategy, an English or German learning child would never come to a correct segmentation of iambic words or of typically unstressed function words. But there is evidence that already by the end of their first year, children treat iambic words as units (Juscyzk et al. 1999) and recognize high-frequency function words as units that are separable from their context (Höhle and Weissenborn 2000; Höhle and Weissenborn 2003). This suggests that children have integrated additional information into their segmentation routines, such as for instance allophonic information (Jusczyk et al. 1999), phonotactic information (Mattys and Jusczyk 2001), and knowledge of frequently co-occurring patterns in the input (Saffran et al. 1996). There is empirical evidence that children initially focus on prosodic information and start to integrate nonprosodic segmental information only later (Jusczyk et al. 1993; Morgan and Saffran 1995; but: Thiessen and Saffran 2003). By the age of 9 months children use prosodic as well as nonprosodic segmental cues, but in case of conflicts between these different sources of information, prosody still overrides the segmental cues (Mattys et al. 1999).

This pattern of an initial prosodic bias that is lost during the first year of life needs further clarification. Is the prosodic bias part of a language specific bootstrapping program or is it due to general restrictions of the auditory system that are shared across species (Ramus et al. 2000)? Even prenatal experience may be a source for this bias (Jusczyk 1997). The acoustic system of the fetus is already functioning during the last three months of gestation (cf. Lecanuet and Granier-Deferre 1993). Speech uttered by the mother seems to be one of the most salient acoustic stimuli within the intra-uterine environment but the signal — due to a filter function of the uterus — contains only the low-frequency parts. Thus, the fetus is exposed predominantly to the prosodic features of speech, probably leading to the observed attentional bias to this kind of information.

5. Speculations on the further development of bootstrapping approaches

Bootstrapping mechanisms are assumed to help the child find a starting point for acquiring the specific structural knowledge of the native language. As has been shown above, bootstrapping mechanisms have been proposed within very different theoretical frameworks. The uniting feature is the assumption that a genetically fixed program constrains the way language is learned to predetermined steps.

Within the generative framework, this program is part of the domain-specific innate system the child has at her disposal for the task of language acquisition with the single function of connecting UG principles and parameters to the specific properties of a given language. In most of the proposals within the prosodic bootstrapping accounts, the question of what is genetically fixed is discussed in a broader framework of perceptual, cognitive and language processing, their interactions, their changes by biological maturation and by the growing influence of already acquired knowledge by top-down processes (Jusczyk 1997; Werker et al. 1996).

Bootstrapping mechanisms as initially proposed by Pinker (1984) only served the function of constraining the first hypotheses to the specific instantiations of grammatical categories and relations in the language. In the same manner, prosodic bootstrapping as described above by Morgan and Demuth (1996) only serves of the function of an initial segmentation of the speech input into linguistically relevant units. Thus, bootstrapping mechanisms have highly restricted functions for a first organization of the input from which further learning can proceed. As such, they can only be part of a more comprehensive model of language acquisition, as e.g., models of distributional learning or models based on dynamic systems theory (Hirsh-Pasek et al. 1996; see Hockema and Smith this issue; Hohenberger and Peltzer-Karpf this issue).

Looking into the future, there are several issues that should be approached within this framework. First, despite the active research in the field, our picture of the kind of interfaces between linguistic domains that the child can use for bootstrapping is still fragmentary and mainly focused on the prosody-syntax, the prosody-lexicon and the syntax-semantics interfaces. But there might be other cues the child might use to break into the system, e.g., aspects of discourse pragmatics and informational structure (cf. Hamann et al. 1998). Further research on the various interconnections between linguistic domains and their function in language acquisition is necessary to give us a more detailed picture on the exact nature of the task the child deals with.

Second, the assumption of an innate availability of syntactic and semantic notions underlying the semantic and the syntactic bootstrapping accounts is very strongly debated (Bowerman 1990; Fisher 2002; Pye 1990; Tomasello 2000; Tomasello and Abbot-Smith 2002). Within usage base accounts the early existence of such knowledge especially for verbs is questioned. Instead, it is suggested that children's early representations for verbs are organized around individual items and their specific properties and that the child constructs knowledge about general categories and notions from these individual instances (Tomasello 2000). The available data (e.g., Abbot-Smith et al. 2001; Akhtar 1999; Akhtar and Tomasello 1997; Brooks and Tomasello 1999; McClure et al. 2006) provide evidence for verb-specific as well as verb-general knowledge in children between two and three years of age. A proof of the availability or nonavailability of innate linguistic concepts relevant for the assumed bootstrapping mechanisms remains a methodological challenge for future research.

Third, there is a need for a more comprehensive understanding of the bootstrapping mechanisms themselves. Besides the questions concerning their origin already formulated above, their lifetime availability should be a matter of closer consideration. Can bootstrapping mechanisms be used by the older learner or are they restricted to the young learner, i.e., is there a critical period for bootstrapping? This relates directly to the question about bootstrapping in second language learning — are the same or comparable mechanisms working in L2 acquisition (c.f. Carroll 2000)? How does the bootstrapping system work in the case of bilingual acquisition if the system must cope with conflicting input information (Gawlitzek-Maiwald and Tracy 1996)?

The work done within the bootstrapping framework has greatly enhanced our understanding of the abilities the child brings to the task of language acquisition but, as shown, a number of unresolved issues will keep the discussion on bootstrapping mechanisms alive during the coming years.

6. Summary

Bootstrapping mechanisms are mechanisms that help the child to initiate her first steps into the system of the language to be acquired. Initially proposed within the framework of universal grammar by Pinker, they serve the task of connecting the innate linguistic knowledge the child brings to the task of language acquisition to the specific features of the language to be learned. Especially in the domain of proposals subsumed under the heading of prosodic bootstrapping, the function of the mechanisms is seen differently. In these accounts, bootstrapping mechanisms help the child find syntactically relevant units like words, phrases, and sentences that serve as basis for further acquisition. These proposals do not necessarily share the idea of UG. Thus, bootstrapping mechanisms — with slightly different specific functions — are comparable with different theoretical views on language acquisition. Bootstrapping accounts have focused on the acquisition of language specific syntactic regularities, postulating that the child starts the acquisition process based on prosody-syntax and prosody-semantics interfaces. Open questions within this approach concern the reliability of the input cues, the existence of cues that are not subject to crosslinguistic variation and the applicability of the concept to different areas of language acquisition (L2 acquisition, bilingual acquisition, SLI).

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