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# *Domain-General Learning Capacities*

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As far as acquisition of language is concerned, it seems clear that reinforcement, casual observation, and natural inquisitiveness (coupled with a strong tendency to imitate) are important factors, as is the remarkable capacity of the child to generalize, hypothesize, and “process information” in a variety of very special and apparently highly complex ways which we cannot yet describe or begin to understand, and which may be largely innate, or may develop through some sort of learning or through maturation of the nervous system. The manner in which such factors operate and interact in language acquisition is completely unknown. It is clear that what is necessary in such a case is research, not dogmatic and perfectly arbitrary claims, based on analogies to that small part of the experimental literature in which one happens to be interested.

Noam Chomsky (1959), *A review of Skinner’s “Verbal Behavior”*

Language is arguably the most complex system acquired by humans. This fact, combined with the tender age at which language is typically learned, suggests that infants must come to the task of language acquisition already possessing the machinery required to master human language. What remains unknown is the nature of this machinery. Do infants possess dedicated domain-specific learning mechanisms, evolved for language acquisition? Or do infants take advantage of existing learning mechanisms that are not domain-specific to discover the structure of human language? In this chapter, we will consider the current state of the art in disentangling these views. While some progress has been made since Chomsky’s (1959) quotation reprinted above, much still remains unknown.

It is important to note at the outset that the distinction between domain-specific and domain-general learning mechanisms is orthogonal to the nature/nurture issue (e.g., Peretz, in press). These two theoretical debates are often confounded; there is a tendency to assume that innateness entails domain-specific knowledge and/or learning mechanisms. However, all learning mechanisms presumably require innate structure, otherwise there would be no way to get learning off the ground. For example, connectionist

networks – the paramount examples of domain-general learning devices – entail a great deal of “innate” structure, from input representations to learning rules to architectural constraints (e.g., Elman et al., 1996). Domain-general learning mechanisms can thus be innate, and domain-specificity can be learned (witness evidence for localized brain areas subserving learned tasks such as reading and writing).

Domain-specific learning mechanisms are traditionally invoked when learning phenomena are observed that are not seen in other domains. By contrast, domain-general learning mechanisms are invoked when parallel learning phenomena are observed across distinct domains. Importantly, identical learning mechanisms can render very different kinds of knowledge in different domains. This is due to the fact that different domains have different regularities, and that infants face different constraints upon learning in different domains. Because of this, a detailed look at the structure of the to-be-learned domain, along with a close investigation of the operation of any potential learning mechanisms, is necessary before drawing conclusions about domain-generality or domain-specificity. To this end, this chapter will consider relevant empirical evidence and evaluate the extent to which domain-general learning capacities can account for the acquisition of natural languages. In particular, we will focus on the areas of speech perception, speech category learning, word segmentation, word learning, and syntax, aspects of language where domain-specificity has been an explicit focus of investigation.

## Historical Issues: Chomsky versus Skinner

The conflict between domain-specific and domain-general views of language acquisition has its roots in an influential debate from the mid-twentieth century, with reverberations that extended far beyond the field of language. In 1957, B. F. Skinner published his classic volume, *Verbal Behavior*, which laid out his behaviorist theory of language acquisition. Skinner invoked equipotential mechanisms for language acquisition via operant conditioning: the detection of contingencies between observable entities. Language acquisition could thus be explained based on the organism’s history of experiences and reinforcement, via the same mechanisms observed for learning in other domains and species.

In his devastating critique of Skinner’s theory, Chomsky (1959) argued convincingly that internal representations are needed to explain language behavior. An internalized grammar allows learners to go beyond the particular sentences in the input, permitting generalization. By structuring the problem of language learning around the acquisition of a grammar, Chomsky radically altered the field’s conceptualization of what language acquisition entails. This, in turn, suggested a need for more specialized learning mechanisms: “The fact that all normal children acquire essentially comparable grammars of great complexity with remarkable rapidity suggests that human beings are somehow specially designed to do this, with data-handling or ‘hypothesis-formulating’ ability of unknown character and complexity” (Chomsky, 1959). Subsequent theoretical innovations led to a proposed language acquisition device – innate linguistic knowledge in the

form of a universal grammar, tied to dedicated language learning processes (Chomsky, 1965, 1968). Chomsky's early views continue to be extremely influential. In particular, there is no doubt that Skinner's central claims were incorrect; external reinforcement cannot explain child language acquisition. However, recent research has begun to examine other potentially general learning mechanisms that may play a role in language acquisition; these theoretical and empirical innovations will be the focus of the remainder of this chapter.

## Speech Perception

Speech is a uniquely human capacity that is closely tied to language. As such, speech perception is often regarded as a likely domain in which to find evidence for domain-specific learning mechanisms. Many aspects of this investigation can be viewed as attempts to answer a deceptively simple question: Is speech special? That is, does speech perception invoke unique (and uniquely human) processes? One of the most compelling arguments advanced in favor of the claim that speech is special is based upon the phenomenon of categorical perception in speech perception. Categorical perception is said to occur when discrimination is determined by category identification: listeners discriminate between-category contrasts, but cannot discriminate between members of the same category. For example, in Liberman, Harris, Hoffman, and Griffith's (1957) classic experiment, listeners were able to discriminate more easily between /b/ and /d/ (a cross-category distinction) than between two different examples of /b/, even though the two examples of /b/ were as acoustically different as the cross-category pair. Other early experiments indicated that discrimination of non-speech stimuli was continuous, not categorical (Mattingly, Liberman, Syrdal, & Halwes, 1971), and that even very young infants show evidence of categorical perception for speech (Eimas, Siqueland, Jusczyk, & Vigorito, 1971). These results, and many others, were consistent with the theory that speech perception involves unique processes not seen in other domains (e.g., Eimas, 1974).

Later evidence was not consistent with this theory. Animal experiments demonstrated that a variety of non-human species perceive speech sounds categorically (e.g., Kuhl & Miller, 1975). Further, both adults and infants show categorical perception for many non-speech stimuli, including music-like sounds (e.g., Cutting & Rosner, 1974), faces (e.g., Etcoff & Magee, 1992), and color (e.g., Bornstein, Kessen, & Weiskopf, 1976). Categorical perception is more robust for stop consonants (e.g., /b/ and /k/) than it is for vowels (e.g., Pisoni, 1975). These differences have led to proposals that there are specialized memory systems for stop consonants and vowels (e.g., Schouten & van Hessen, 1992). However, categorical perception can also be observed to different degrees for *non-speech* sounds that differ in the extent to which they are characterized by rapidly changing acoustic dimensions – just as the acoustic information associated with stop consonants in speech changes more rapidly than vowels (Mirman, Holt, & McClelland, 2004). Considering the wide variety of domains in which categorical perception can be observed, recent theories and modeling work suggest that categorical perception may be an inherent byproduct of perception in any domain where sufficiently dense stimuli

have a categorical structure, though of course categorical perception for speech is also influenced by the characteristics of the peripheral auditory system (e.g., Damper & Harnad, 2000).

In addition to categorical perception, a number of other phenomena were initially considered to support claims of unique processing/learning for speech stimuli. For example, duplex perception occurs when speech sounds, split into two streams and presented binaurally, simultaneously give rise to two distinct perceptual experiences (Fowler & Rosenblum, 1990). Initially, duplex perception was thought to occur only with speech; however, similar phenomena are seen with musical stimuli (e.g., Hall & Pastore, 1992). Similarly, the right ear advantage – in which sounds presented to the right ear can be detected at lower amplitudes than sounds presented to the left ear – was initially linked to the left hemisphere's specialization for language (e.g., Glanville, Best, & Levenson, 1977). However, the right ear advantage can also be demonstrated for non-linguistic stimuli such as tones or the “dot–dot–dashes” of Morse code in highly trained Morse operators (Brown, Fitch, & Tallal, 1999; Papçun, Krashen, Terbeek, Remington, & Harshman, 1974). Finally, the McGurk effect – an effect of visual information on the perception of an auditory stimulus (MacDonald & McGurk, 1978) – can also be found in the realm of music perception (Saldaña & Rosenblum, 1993). The fact that all of these phenomena also characterize non-linguistic perception suggests that the underlying mechanisms are domain-general, not specific to language.

While behavioral parallels between speech and non-speech domains are compelling, they fail to address an important question: Why are speech and language processing so consistently organized across individuals, tending to be centralized in the left hemisphere (e.g., Hickok, 2001)? Indeed, there are clear neurological differences between processing a sound when it is perceived as speech and when it is perceived as non-speech, even if the stimulus is identical (e.g., Dehaene-Lambertz et al., 2005). Further, event-related potential (ERP) data indicate that phoneme processing may invoke substantially similar neurological processes early in infancy and in adulthood (Dehaene-Lambertz & Baillet, 1998; Dehaene-Lambertz & Gliga, 2004). Given the behavioral similarities between processing speech and non-speech (e.g., categorical perception, duplex perception), it seems initially incongruous that there would be a brain region dedicated to speech processing, one that is at least partially consistent between infancy and adulthood.

Note, however, that different brain regions need not imply different domain-specific learning mechanisms. Zatorre and colleagues (Zatorre, 2001; Zatorre, Belin, & Penhune, 2002) have suggested that the left hemisphere may be better suited to processing transient stimuli that require high temporal resolution due to the nature of its neural connections. Further, regional specificity in the brain may be related to factors other than unique learning mechanisms. For example, many species preferentially attend to same-species vocalizations. This preference appears to be mediated by the activation of specific brain regions that represent or respond to same-species utterances (Wang & Kadia, 2001; Wang, Merzenich, Beitel, & Schreiner, 1995). If, in these species, neural specialization or specific recruitment is related to attentional biases toward conspecific vocalizations, the same may be true of human infants. Infants' brains may be geared to be particularly responsive to human speech. Consistent with this view, Vouloumanos and Werker

(2004) demonstrated that even 2-month-old infants have a reliable preference for human speech over a variety of other auditory stimuli.

Therefore, it may be that speech is special in one important way: infants appear to attend preferentially to speech, which may ensure that speech is a particularly important feature in their environment (Vouloumanos & Werker, 2004). The phenomena that appear unique to speech, or more frequently observed in speech, may in fact arise from an interaction between the acoustic characteristics of speech and our extensive experience listening to speech. This supposition is borne out by the fact that similar phenomena arise in other domains with comparable stimulus density (e.g., categorical perception in face recognition), acoustic characteristics (e.g., right ear advantage for tone discrimination, duplex perception of chords), and familiarity (e.g., right ear advantage in trained Morse code operators.). While early-developing or innate attentional biases favoring speech ensure that it is highly salient in a way few other stimuli are, there is mounting evidence to suggest that speech perception is influenced by the same learning mechanisms that are responsible for processing other types of stimuli. This parallel is most clearly seen in face perception: infants' early propensity to attend to face-like stimuli combines with subsequent experience to affect children's categorical perception of facial emotion displays (Pollak & Kistler, 2002).

## Speech Categories

Across different languages, different acoustic contrasts are meaningful. For example, the distinction between /r/ and /l/ indicates different meanings in English (the difference is "phonemic," as in "rock" vs. "lock"), but not in Japanese. Infants must learn which acoustic distinctions are productive in their linguistic environment. This knowledge is acquired rapidly; infants adapt their responses to the phonemic categories of their language within the first year of life (see Polka, Rvachew, & Mattock, this volume). The mechanism that makes this learning possible may involve sensitivity to the statistical structure of the linguistic input, in the form of the distribution of speech sounds in the linguistic environment (see Gerken, this volume). A variety of non-human animals show similar attunement to particular acoustic contrasts in response to information about the distribution of speech sounds (e.g., Kluender, Lotto, Holt, & Bloedel, 1998). This suggests that learning about phonemic categories may arise from the same mechanisms as learning about any type of category.

Even newborns can categorize (Slater, 1995). Just as infants adapt to the speech sound categories of their native language in response to perceptual information, infants' early object categories are based on perceptual, rather than conceptual, information (e.g., Mandler, 2000; Quinn & Eimas, 2000). Also, just as distributional information plays an important role in infants' adaptation to phonemic categories, the frequency and distribution of infants' experience with different exemplars influences developing object categories. When presented with a set of exemplars with a highly variable distribution, infants form broad, inclusive categories. When familiarized with a more focused distribution of exemplars, infants form categories with tighter boundaries (e.g., Oakes &

Spalding, 1997). In a similar vein, Huttenlocher, Hedges, and Vevea (2000) demonstrated that adults' identification of exemplars is influenced by the previous distribution of category members they have experienced.

Huttenlocher, Hedges, Corrigan, and Crawford (2004) argue that a process critical to inductive categorization is the formation of categories that capture the distributional density of previously experienced exemplars. Ideally, categories should be formed with a prototypical member near the center of the distribution, the region of the highest density of exemplars. Category boundaries should be placed in regions with low exemplar density. Categories with these characteristics are efficient; placing category boundaries in sparsely populated regions means that there is less likelihood of misclassifying stimuli. Maye, Werker, and Gerken (2002) demonstrated that adults and infants place stimulus boundaries in regions of low density in response to different distributions of speech sounds. Therefore, it seems quite plausible that infants' ability to adapt to their language's categories of speech sounds may be a specific instance of a more general tendency to use distributional information as a cue to categorization. Note, however, that previous experience can prevent learners from forming efficient categories. Most famously, previous experience with a language that does not use a phonemic contrast (such as /r/ and /l/ in Japanese) can lead to difficulty acquiring the distinction in response to new acoustic distributions in a new linguistic environment. Similarly, perceptual biases can influence category formation. Japanese listeners find English /r/ to be more dissimilar to Japanese /r/ than English /l/, which has been proposed to explain why native Japanese speakers show more improvement in their use of /r/ than /l/ when learning English (Aoyama, Flege, Guion, Akahane-Yamada, & Yamada, 2004). Infants' and adults' discovery of speech categories is likely to be strongly influenced by the similarity of different speech sounds in their language.

Infants need not only to learn which acoustic distinctions are phonemic in their language. They must also learn how to appropriately produce the sounds comprising the phonemic inventory of their language. Perceptual input will, of course, play an important role in specifying infants' productive repertoire. Additional learning mechanisms must play a role, though. Goldstein, King, and West (2003) have demonstrated that social shaping plays an important role in allowing infants to converge upon language-appropriate verbal behavior, paralleling the development of birdsong. Sounds that receive more social response are more likely to recur, shaping the communicative inventory for future interactions, as demonstrated in the domain of infant babbling (Goldstein et al., 2003). Thus, humans and non-humans may share some learning mechanisms that support the development of productive communicative abilities.

## Word Segmentation

Unlike the blank spaces between words in text, speakers do not consistently place pauses between words in fluent speech. This presents a challenge to young infants who must locate word boundaries. Despite the complexity of this task, infants are able to segment words from fluent speech by at least 7 months of age (Jusczyk & Aslin, 1995).

One cue that allows infants to discover words in fluent speech is sequential statistical information. Syllables within a word are more likely to occur together than syllables that are not part of the same word. Saffran, Aslin, and Newport (1996) provided evidence that both infants and adults are capable of using transitional probabilities between syllables to detect word boundaries in fluent speech. Statistical learning mechanisms are available across species (e.g., Hauser, Newport, & Aslin, 2001), and in a variety of domains. Adults and infants attend to transitional probabilities in visual stimuli and non-linguistic auditory stimuli (Fiser & Aslin, 2001; Saffran, Johnson, Aslin, & Newport, 1999).

Sequential statistical cues are available to infants from very early in life (Kirkham, Slemmer, & Johnson, 2002), and may play a role in infants' earliest segmentation of words from fluent speech (Thiessen & Saffran, 2003). However, infants also use another kind of cue to word segmentation: acoustic cues. For example, in English, stress is correlated with word beginnings, and between 8 and 9 months, infants begin to treat stressed syllables as word onsets (Jusczyk, Houston, & Newsome, 1999). While young infants favor transitional probabilities over stress cues, older infants rely more on stress cues (Johnson & Jusczyk, 2001). Infants may learn to use these acoustic cues to word boundaries via the same statistical learning abilities that allow infants to take advantage of transitional probabilities.

Statistical learning can be more broadly construed as attention to regularities in the environment. Attending to such regularities allows learners to discover which events predict other events (e.g., Canfield & Haith, 1991). On this interpretation, attention to transitional probabilities between elements in sequence is only one particular example of statistical learning. To discover acoustic regularities such as lexical stress, infants require experience to indicate which acoustic events have predicted word positions on previous occasions. To do so, infants must be familiar with at least a few words (possibly discovered via transitional probabilities in fluent speech, or heard in isolation). From these words, infants can detect which acoustic characteristics are correlated with word positions; for example, once infants are familiar with a few words, it is possible for them to discover that most of those words begin with a stressed syllable, and to begin to treat stress as a cue to word onsets (Swingley, 2005). Chambers, Onishi, and Fisher (2003) have suggested that similar learning mechanisms may allow infants to discover which sound combinations are permissible in their language. For example, in English, "fs" is not permitted in word-initial position; discovering these types of regularities can help infants segment fluent speech (Mattys, Jusczyk, Luce, & Morgan, 1999). With age and experience, infants become able to integrate multiple cues to word segmentation (e.g., Morgan & Saffran, 1995). A similar developmental progression – from reliance on single cues to weighting of multiple cues – is seen in object categorization (Younger & Cohen, 1986). Therefore, it seems likely that the developmental trajectory underlying infants' use and integration of multiple cues arises from domain-general processes.

## Words and Meaning

Learning the meaning of words is one of the great milestones of early development. The majority of the research on infants' word learning has focused on nouns. In this context,

“meaning” refers to the connection between a noun and the object to which it refers. This connection is often assessed via comprehension measures (such as looking), because infants comprehend far more words than they can produce (e.g., Benedict, 1979). Word learning is slow before the first birthday, but it does occur; for example, 6-month-olds look longer at a picture of their mother in response to the word “Mommy” (Tincoff & Jusczyk, 1999). Between their first and second birthday, children begin to learn words more easily (Bloom, 2000; Werker, Cohen, Lloyd, Casasola, & Stager, 1998). One of the most impressive abilities children demonstrate during this period is “fast-mapping,” the ability to form a connection between words and referents with as little as one exposure (Heibeck & Markman, 1987). This seemingly unique phenomenon has prompted speculation that humans may possess a dedicated word-learning mechanism (e.g., Waxman & Booth, 2000).

To assess the claim that word learning is the result of a domain-specific mechanism, we must examine the processes that enable word learning. One process that is critical to word learning is the ability to detect correspondences between words and objects, and to form an association between them. Objects that are regularly present when a word occurs are likely candidates as referents for that word, at least for nouns (e.g., Plunkett & Schafer, 1999; Roy & Pentland, 2002). However, word learning is also influenced by a variety of adaptive biases and constraints. The shape bias, for example, refers to children’s tendency to generalize names to novel objects on the basis of shape (Landau, Smith, & Jones, 1988). The principle of mutual exclusivity holds that any object has only one label (Markman & Wachtel, 1988). The whole object bias refers to children’s preference to treat labels as referring to whole objects, rather than parts of objects (Soja, Carey, & Spelke, 1991). Finally, when children learn the name of an object, they tend to treat that label as a reference to a class of objects (such as dogs), rather than a single object; this is called the taxonomic bias (Markman & Hutchinson, 1984).

The origin of these biases is uncertain. One possibility is that they are both innate and specific to language, as has been argued for the whole object, taxonomic, and mutual exclusivity biases (e.g., Markman, 1991, but see Markman, 1992; for discussion, see Diesendruck, this volume). Alternatively, these biases could be specific to language, but arise from domain-general learning mechanisms. Infants’ early experience with words may highlight linguistic regularities that facilitate subsequent word learning (e.g., Landau, Gershkoff-Stowe, & Samuelson, 2002; Samuelson, 2002). Finally, it may be the case that these biases are the result of domain-general constraints on the mechanisms that make word learning possible. For example, mutual exclusivity may arise from the fact that forming an association between two stimuli, X and Y, makes forming subsequent associations between one of those stimuli (X) and a new stimulus (Z) more difficult (e.g., Mackintosh, 1971). Many questions remain to be answered about the parallels between word learning and learning in other domains before it will be clear which of these positions is correct (e.g., Halberda, 2003; Sabbagh & Gelman, 2000).

A third source of information for word learning is social interaction. Infants are sensitive to the social intent of speakers in word-learning situations (see Baldwin & Meyer, this volume). An important direction for future research will be to examine the interactions between these sources of information. For example, there are likely to be several potential referents in the environment each time a word occurs. If an infant depends on statistical information alone, word learning will be extremely difficult (Bloom, 2000).

Social cues to referential intent can facilitate word learning. Similarly, the effect of constraints on word learning can be influenced by the pragmatic and perceptual context in which words are taught (Diesendruck, Gelman, & Lebowitz, 1998). As these examples illustrate, multiple domain-general learning mechanisms – such as statistical learning and social learning – can combine to create domain-specific knowledge (the meaning of words).

Any domain-general account of word learning, though, must account for fast-mapping, the signature phenomenon thought to demonstrate a unique mechanism for word learning. Critically, Markson and Bloom (1997) have demonstrated that children “fast-map” novel facts about objects as well as their names. These results suggest that fast-mapping is a specific realization of a general capacity. Evidence for fast-mapping in a dog (Kaminski, Call, & Fischer, 2004) has similar implications. However, the possibility that lexical learning arises from domain-general mechanisms does not imply that lexical learning proceeds in precisely the same manner as other types of learning. For example, whereas children extend names to other objects in the same category, children are more limited in their extensions of facts (e.g., Waxman & Booth, 2000). This difference may be due to the fact that general learning mechanisms render different knowledge as a function of the structure of the domain being acquired (Saffran, 2001a). When children learn the names of objects, those names frequently apply to all of the other objects in that category. Facts (such as “my uncle gave me this one”) apply only to one individual object; they are like proper nouns (Bloom & Markson, 2001). The contrast between facts and words illustrates that learning mechanisms can give rise to very different knowledge based on children’s experience.

## Syntax

Along with speech perception, syntax is the aspect of language where domain-specificity has been most widely assumed. This domain-specificity takes two forms: innate linguistic knowledge (in the form of a universal grammar) and domain-specific learning mechanisms (e.g., triggering mechanisms in the principles and parameters framework; see Goodluck, this volume). Domain-specificity has been implicit in many of these theories for at least three reasons. First, syntax is typically abstract, and not transparently mirrored in the surface structure of the input, suggesting the need for dedicated machinery. Second, the languages of the world contain remarkably little syntactic variation, a fact that is readily explained by hypothesizing innate linguistic knowledge (e.g., Baker, 2001). Third, non-human animals have difficulty acquiring human syntactic structures; these species differences can be explained by hypothesizing dedicated human linguistic machinery.

However, evidence is mounting that at least some syntactic regularities may be learnable by domain-general mechanisms. For example, consider the acquisition of grammatical categories – determining which words are nouns, which are verbs, etc. Children are able to appropriately use grammatical category information by the middle of the second year (e.g., Bloom, 1970; Brown, 1973). Prominent semantic bootstrapping accounts of

this phenomenon rely on innate linguistic knowledge concerning semantic–syntactic correspondences (e.g., Pinker, 1984). More recent accounts, however, building from an earlier proposal by Maratsos and Chalkley (1980), have argued that infants could discover which words cohere into grammatical categories by tracking patterns of co-occurrence of words in the input (e.g., Mintz, Newport, & Bever, 2002; Redington, Chater, & Finch, 1998). For example, one might discover the category Noun by determining that a certain set of words was typically preceded by “the.” While there are many individual counterexamples (Pinker, 1985), computational analyses suggest that the information needed to cluster words into categories is available in child-directed speech, and adults learning artificial languages can discover grammatical categories using solely distributional information (Mintz, 2002). While these findings do not directly demonstrate domain-general learning, as the materials are always linguistic, categorization via distributional information is unlikely to be limited to language learning.

Other lines of research have directly addressed the issue of domain-general versus domain-specific learning mechanisms by contrasting the use of linguistic and non-linguistic “grammars.” Building on research by Morgan and Newport (1981; Morgan, Meier, & Newport, 1987, 1989), Saffran (2001b, 2002) investigated the use of distributional information for discovering linguistic phrase structure, a widespread aspect of syntactic structure cross-linguistically. Adults can use a statistical cue to phrasal units, predictive dependencies (e.g., the presence of “the” or “a” strongly predicts a noun somewhere downstream), to discover phrase boundaries (Saffran, 2001b). Moreover, adults and children are better at acquiring languages that contain predictive dependencies than those that do not (Saffran, 2002). Interestingly, the same constraint on learning emerges in tasks using non-linguistic materials, including both auditory non-linguistic grammars (in which the “words” were computer alert sounds) and visual non-linguistic grammars (simultaneously presented arrays of shapes). Saffran (2002, 2003a) hypothesized that this domain-general learning mechanism has played a role in shaping the structure of natural languages. On this view, languages contain predictive dependencies as cues to phrasal units because this information helps human learners to discover phrases in natural languages. A domain-general learning ability may have shaped the structure of something quite specific – language.

## Challenges for Domain-General Accounts

How does one “prove” that a learning mechanism is domain-general? Even the clearest cases – where learners show equivalent performance when acquiring materials from two different domains, given the same patterns in the input – could equally well represent two parallel learning mechanisms in lieu of a single domain-general mechanism. Here we see a logical problem with demonstrations of domain-general learning: while parsimony might suggest that one learning mechanism is better than two, the natural world is not always parsimonious. One approach to this problem would be to attempt to identify the neural basis of the learning mechanisms in question. In this attempt, though, it is important to remember that the use of distinct brain areas by expert users of a system

(e.g., adults) does not necessarily signal the use of distinct learning mechanisms (for discussion, see McMullen & Saffran, 2004; Peretz, in press).

Other objections to claims of domain-general learning arise from the empirical data themselves. Some mechanisms used for language learning, such as rule-pattern detection (Marcus, Vijayan, Rao, & Vishton, 1999), may not readily operate over all non-linguistic stimuli (Marcus, Johnson, & Fernandes, 2004). However, they are apparently usable by non-human primates (Hauser, Weiss, & Marcus, 2002), and do operate over at least some non-linguistic stimuli (Saffran, Pollak, Seibel, & Shkolnik, submitted). More generally, debate continues over the degree to which complex syntactic structures require domain-specific innate knowledge, or whether they can instead be explained with reference to more general cognitive/social/pragmatic mechanisms (see Lidz, this volume). Evidence from circumstances in which children create their own languages, as in creolization (e.g., Senghas, Kita, & Ozyurek, 2004) and homesign (e.g., Goldin-Meadow, 2003), may help to resolve some of these issues. In such cases, there is a far greater divergence between the structure of the input and the child's eventual linguistic attainments, allowing for a careful parsing of the types of learning mechanisms in operation.

Other objections stem from the overall contour of the evidence concerning child language acquisition. For example, if children are relying on general learning mechanisms to acquire language, then why are they markedly more successful than non-human primates? That is, if language learning doesn't rely on anything special about language, why do only humans do it so well? The answer to such objections may well lie in the specifics of how the learning mechanisms work – as opposed to taking “language” and “cognition” as unitary constructs. For example, there are likely to be specific cognitive differences between humans and non-humans that may affect language learning, even if these differences did not evolve specifically to support language acquisition (e.g., Hauser, Chomsky, & Fitch, 2002). Recent evidence points to differences in the use of learning mechanisms across species that may affect language learning outcomes. For example, given transitional probabilities computed over non-adjacent syllables (with other syllables intervening between the target syllables), human and tamarin learners show quite different patterns of performance (Newport & Aslin, 2004; Newport, Hauser, Spaepen, & Aslin, 2004). Both species show limitations in the types of patterns they detect. Critically, however, the kinds of limitations observed in humans map onto natural language structures – segmental non-adjacency patterns that occur in languages are learnable by humans – whereas the tamarins' learning abilities appear to be unrelated to the structures observed in natural languages. The fact that humans also exhibit related constraints when acquiring non-linguistic sequences such as tones (Creel, Newport, & Aslin, 2004) supports the contention that non-linguistic limitations on what is learnable may have shaped the organization of human languages.

A related objection pertains to the contrast between child and adult learners. If language acquisition rests on general learning abilities, then wouldn't one expect adults to outperform children, when in fact the available evidence suggests that it is the other way around? Again, this sort of objection makes the assumption that there is some sort of overarching “general learning ability.” This apparent paradox may be resolved by considering other features of cognition that distinguish children and adults. For example, Newport (1990) has argued that children's relatively constrained working memory

capacities may in fact facilitate some aspects of language learning. Combinatorial systems like morphology and syntax require the discovery of small component pieces of language in order to discover the patterns that relate them. The sieve-like nature of children's memories might facilitate the discovery of these pieces, whereas adults are more likely to remember larger chunks of language, missing the underlying patterns. Consistent with this hypothesis, adults actually appear to learn certain aspects of novel languages more successfully when engaged in a concurrent capacity-limiting task (Cochran, McDonald, & Parault, 1999).

Evidence from atypical development is often raised in objections to domain-general accounts. The classic picture is that of a double dissociation, in which "language" is spared while "cognition" is disrupted as in Williams syndrome (WS) (e.g., Pinker, 1991; Rossen, Jones, Wang, & Klima, 1995), while the opposite pattern is obtained in specific language impairment (SLI) (Crago & Gopnik, 1994; Rice, 1999). These kinds of findings are taken as evidence for a distinction between abilities used to learn language and the rest of cognition; for example, Pinker (1999) contrasts individuals with SLI and WS by noting that "the genes of one group of children impair their grammar while sparing their intelligence; the genes of another group of children impair their intelligence while sparing their grammar" (p. 262). One reason that this picture of a clean double dissociation originally emerged is that language and cognition were each taken as unitary constructs. However, when the multiple interlocking subcomponents of language and cognition are considered, the picture of strengths and weaknesses within particular populations becomes more complex (e.g., Shatz, 1994). For example, individuals with WS show atypical language abilities in a number of subdomains, from word segmentation (Nazzi, Paterson, & Karmiloff-Smith, 2003) to morphosyntax (Karmiloff-Smith et al., 1997), suggesting that the intact language hypothesis in this population is a myth (for review, see Karmiloff-Smith, Brown, Grice, & Paterson, 2003). Similarly, individuals with SLI show impairments in non-"core" language abilities such as speech perception (Joanisse & Seidenberg, 1998), the use of symbolic representation (Johnston & Ramstad, 1983), and verbal working memory (Weismer, Evans, & Hesketh, 1999). This more complex picture of these disorders does not rule out the existence of specialized learning capacities. However, it does suggest that the classic double-dissociation argument is less clearly applicable than was previously believed.

## Conclusions

"Domain-general" is a loaded term. It implies a set of generalized simple learning devices that can operate over any types of input, such as those espoused by Skinner. The literature that we have reviewed suggests that this is an overly simplistic view of the learning abilities that likely contribute to language learning. These learning mechanisms are constrained to operate over some types of input but not others, as a function of human perception and cognition. They may incorporate both innate and emergent properties. And much of the power of the mechanisms in question likely lies in the ways in which they mutually interact; for example, once learners perform distributional analyses that

render categories, the input to learning changes, such that learners can begin to acquire patterns over categories (types) rather than over the raw input (tokens).

“Domain-specific” is also a loaded term, which usually implies an innate, modular, knowledge system. It is evident, however, that domain-specificity and innateness are rightly viewed as orthogonal variables. Modularity can emerge as a function of experience within a particular domain. While the adult state clearly involves some localization of cognitive and linguistic functions, this domain-specificity might be the end-result of domain-general mechanisms operating on material drawn from different input domains (e.g., McMullen & Saffran, 2004). The structure of the input-to-be-learned will influence the eventual outcome of learning, such that the same mechanism can obtain different results as a function of prior knowledge about the input domain (e.g., Saffran, 2001a, 2003b), the age of the learner (e.g., Saffran & Griepentrog, 2001), the structure of the input (Gerken, 2004; Saffran, Reeck, Niehbur, & Wilson, 2005), or the species of the learner (Newport et al., 2004). In addition, a developmental perspective is likely to be quite useful in disentangling initial states from eventual outcomes, for both typically and atypically developing populations (e.g., Karmiloff-Smith, 1998). Technological advances may also facilitate researchers’ ability to ask whether distinct brain areas subserve the acquisition of distinct domains of knowledge early in infancy (e.g., Peña et al., 2003). Returning to the Chomsky (1959) quotation with which this chapter began, it is clear that continued research, rather than dogma, is needed in order to render the most significant progress on the question of domain-specificity and domain-generality in language acquisition.

## Note

Preparation of this chapter was supported by grants to the first author from NICHD (R01HD37466) and NSF (BCS-9983630). We thank Katharine Graf Estes, Michael Kaschak, Erin McMullen, Isabelle Peretz, and David Rakison for helpful comments on a previous draft.

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