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Changing Language

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1. Introduction

One of the central questions facing researchers interested in language is why languages are structured the way that they are. Based on Chomsky's influential research (e.g., Chomsky, 1965; 1981), many scholars have approached this question starting from the assumption that there are universal principles governing the structure of naturally occurring human languages, and that these principles may be a part of the genetic heritage of the human species (see Pinker, 1994, for a well-known explication of this view). The existence of such universal principles, often referred to as innate Universal Grammar, explains why languages have similar structure across the globe and provides a theoretical basis for exploring questions regarding the acquisition of language in children (e.g., Pinker, 1989) and the evolution of language in our species (e.g., Pinker & Bloom, 1990). Universal Grammar (and the broader generativist approach to linguistics) has been useful in setting the terms of many debates surrounding the acquisition of language (e.g., Chomsky, 1965; Seidenberg, MacDonald & Saffran, 2002) and the ways that languages change across historical time (e.g., Lightfoot, 1991; 1999). A side effect of this theoretical approach, however, has been to grant language a special, unique status within the more general cognitive apparatus, and therefore to divorce examination of linguistic structure (and the acquisition of that structure) from examination of other aspects of the cognitive apparatus: memory, attention, categorization, social cognition, and the like.

Functionalist approaches to linguistics take a different tack in explaining why languages are structured the way they are. Rather than treating linguistic knowledge as special and unique within the cognitive apparatus, functional approaches embrace the idea that knowledge of language does not hold special cognitive status. Thus, for example, the acquisition and use of linguistic categories should follow the same principles that govern the acquisition and use of categories in other domains of knowledge (e.g., Taylor, 1998). An oft-repeated phrase in functionalist linguistics captures this notion succinctly: Knowledge of language is knowledge (e.g., Goldberg, 1995). The functionalist perspective posits that languages are structured as they are because of the interplay between linguistic input, human cognitive processing, and the social factors that impact the processing and production of language as they occur in real time. Christiansen and Chater's (2008) approach to language evolution represents an example of such a view, suggesting that the brain was not shaped by the need to acquire language; rather, language was shaped by our brains' ability to learn from linguistic input. Young children have certain limitations on their learning abilities (e.g., Newport, 1990; Saffran & Thiessen, 2003; Hudson Kam & Newport, 2009). Based on these limitations, linguistic structures that are more difficult to learn are less likely to be transmitted across generations of language users, and over time this learning bottleneck constrains the possible forms that a language can take to include only those forms that are comparatively more learnable.

The position advocated by Christiansen and Chater (2008) , among others, suggests that understanding how languages are shaped, and how they work, requires attending to events and changes that have occurred over multiple timescales. These include long-term changes, such as those that have occurred over the course of the evolution of the human species, and linguistic changes of the sort that historical linguists have detailed as occurring over the course of decades and centuries (e.g., Labov, 1994; 2001). These events also include relatively short-term changes, such as the behaviors that develop as we use language across the lifespan and the comparatively minor adjustments to the comprehension and production of language that occur every time we have a conversation (e.g., Clark, 1996; Giles, Coupland & Coupland, 1991). Rather than assuming that linguistic knowledge crystalizes at some point early in one's life and that the structures of a language are unchanging within the individual, this perspective highlights the malleability of linguistic behavior. The linguistic behavior of individual people and the patterns of usage within a language community are in a constant state of flux. Some of these changes may reflect temporary adaptations to a given circumstance (e.g., adjusting one's perceptual representations to accommodate an unfamiliar accent; Sumner & Samuel, 2009). However, under the right circumstances, local changes that occur when speakers make contact with each other can spread through a linguistic community and produce language change on a broader scale (e.g., Labov, 2001).

Understanding why languages are structured the way that they are, then, requires considering not only the kinds of changes in linguistic behavior that occur over broad stretches of time (years, decades, centuries), but also the way that local adaptations of linguistic behavior contribute to these broader changes. The past decade has witnessed rising interest in studying the adaptations in linguistic processing that occur on comparatively short timescales (minutes, hours, and days). Research in this area has largely focused on changes to phonological representations (e.g., Kraljic & Samuel, 2005; Sumner & Samuel, 2009) and to syntactic patterns (e.g., Kaschak & Glenberg, 2004; Wells et al., 2009). The flexibility in performance demonstrated by these studies confirms that adult language use remains open to change (as suggested by the functionalist perspective), and this research has begun to answer questions about how linguistic knowledge is acquired, stored, and changed.

The purpose of this chapter is to present an overview of recent work demonstrating learning and adaptation effects in phonological and syntactic representations. We have two goals. First, in reviewing these two strands of research from the past decade or so, we hope to highlight the commonalities and differences between adaptations that occur within the phonological and syntactic domains. This will help us to extract more general principles that govern how linguistic behavior changes as a function of experience. Second, we will also look at cases where the linguistic adaptations appear to follow principles that have been advanced in the study of other domains of cognitive performance, particularly memory. Such demonstrations will bolster the case for the functionalist claim that knowledge of language is just like other sorts of knowledge, and that learning within language follows the same general patterns that govern learning in other domains.

2. Syntactic Adaptations

Psycholinguistics was born as a branch of cognitive science in the fallout of the famous Chomsky-Skinner interchange. Chomsky's (1959) evisceration of Skinner's (1957) behaviorist approach to language acquisition helped to propel the rising cognitive revolution by demonstrating the need to consider internal mental representations when thinking about how languages are learned and subsequently used. From the start, then, psycholinguists have focused on the notion that there is a fixed internal grammar (the "rules" of language), and the question of how linguistic input was processed in order to recover the syntactic structure of a sentence was a question of major interest. Along the way, there were some doubts about the necessity of positing a fixed internal grammar (e.g., Haviland & Clark, 1974), but it was not until the later development of theoretical approaches such as the Competition Model of Bates and MacWhinney (1989) and constraint-based theories of sentence comprehension (e.g., MacDonald, Pearlmutter & Seidenberg, 1994) that accounts admitting of the possibility of flexibility in syntactic representations were pursued with much vigor.

Constraint-based theories of sentence processing posit that language users track the probability of a range of linguistic events (e.g., How often do certain words co-occur? How often do certain syntactic structures occur? How often do particular verbs appear in a given syntactic structure?, and so on), and use this probabilistic information to make real-time decisions about the most likely interpretation of an incoming sentence. The representation of grammatical knowledge was probabilistic, opening the possibility that as the probabilities of certain events in one's linguistic input changed, the representation of grammatical knowledge would also change. Although this was a straightforward prediction of the constraint-based approach to sentence processing, early work in this domain focused largely on how the long-range probabilistic structure of language (e.g., estimates of the relative frequency of different syntactic structures that were derived from large corpora of language use; see Jurafsky, 1996) affected sentence comprehension. Exploring learning and adaptation effects within experimental paradigms has been a comparatively recent development.

Kaschak and Glenberg (2004) report one of the earliest studies of syntactic adaptation in language comprehension. In a series of experiments, they explored what happened when participants were exposed to a novel syntactic construction. The novel construction was dubbed the *needs* construction, and is exemplified by sentences such as, "*The meal needs cooked* before the guests arrive." This construction is a feature of the dialect of American English spoken in the midlands region (most famously around Pittsburgh), but was unfamiliar to the upper Midwestern participants in the experiments. Within a handful of exposures to this novel construction, participants trained on the new construction were able to process it as quickly as control participants process the version of the construction used in their dialect (*The meal needs to be cooked* before the guests arrive"). That is, participants quickly adapted to the new syntactic feature.

It is important to note that participants trained on the *needs* construction were able to generalize their ability to process it beyond the input presented during initial training. Kaschak and Glenberg (2004) demonstrated that participants generalized the construction to at least one additional verb (*wants*, as in, "*The dog wants walked* before it gets too late"), as evidenced by the fact that they processed sentences with the new verb as readily as they processed sentences containing *needs*, and that they were doing so from the very first encounters with the new verb. Kaschak (2006) further showed that learners generalized the *needs* construction to a pseudo-cleft form ("John thinks that *what the meal needs is cooked* before the guests arrive). The fact that participants are readily able to process the *needs* construction with a novel verb and in a different syntactic context helps to strengthen the conclusion that participants in these studies were learning a new syntactic feature (as opposed to simply learning a new use of the verb *needs*).

Kaschak and Glenberg (2004) report one further finding of interest. They were concerned with how the learning of sentences such as, "The meal needs cooked before the guests arrive" would affect the processing of more familiar sentences such as, "The meal needs cooked vegetables to make it complete" (dubbed the *modifier* construction, since *cooked* serves as a modifier in this case). One possibility was that learning the *needs* construction would impair processing the *modifier* construction (since participants had learned that *cooked* was not being used as a modifier in these experiments). However, Kaschak and Glenberg (2004) report the opposite finding: Learning the *needs* construction facilitated processing of the *modifier* construction. This facilitation was found only when processing the *needs* construction early in the experiment involved considering the *modifier* construction. Upon reading, "The meal needs cooked...," participants were expecting *cooked* to be used as a modifier (as evidenced by slower reading times on the subsequent words of the sentence, in which the modifier interpretation was shown to be wrong). This consideration of the modifier interpretation, although it ultimately turned out to be the wrong interpretation of the *needs* construction sentences, was remembered and available to facilitate the processing of the *modifier* construction when it appeared later in the experiment. Participants who did not consider the *modifier* construction earlier in the experiment showed no such facilitation. Thus, the nature of the processing work that was done while initially learning the novel *needs* construction affected the participants' subsequent patterns of language processing.

Casenheiser and Goldberg (2005; Boyd & Goldberg, 2011) have also shown that adults are capable of learning novel syntactic forms. They created a novel construction in which “approach” events are described using a novel syntactic form. Across several studies, Goldberg and colleagues found that adults could readily learn the new construction, could retain their learning over a delay of a week (Boyd, Gottschalk & Goldberg, 2009), and could produce novel utterances with the construction. These data complement Kaschak and Glenberg's (2004) study by indicating that syntactic adaptation can extend beyond modifications of familiar structures to entirely novel forms.

Wells, Christiansen, Race, Acheson and MacDonald (2009; see also Farmer, Fine & Jaeger, 2011) provide another demonstration that changes in one's linguistic environment can change the way that syntactic structures are processed. Wells et al. (2009) explored the processing of sentences with object relative clauses ("The reporter that the senator attacked admitted the error"), which are considerably more difficult to understand than subject relative clauses ("The reporter that attacked the senator admitted the error"). However, after extensive training on relative clauses, the difference between processing object and subject relatives was greatly attenuated. The finding that the processing of the less-frequent object relative clauses benefited more from the relative clause training than the processing of the more-frequent subject relative clauses is an example of the *inverse frequency effect* (e.g., Ferreira, 2003), wherein lower-frequency forms tend to show larger learning or priming effects than higher-frequency forms.

Luka and Choi (2012; Luka & Barsalou, 2005) provide another demonstration of syntactic adaptation effects. Across a series of studies, Luka and colleagues examined grammaticality ratings for sentences such as, "Debbie ought to buy a car as reliable as that fireman had." These sentences are rated as marginally grammatical at the beginning of the experiments. But after repeated exposure to this type of sentence, grammaticality ratings of sentences with this structure increased. Luka and Choi (2012; Luka & Barsalou, 2005) thus show that participants' assessment of the grammaticality of particular sentence structures can be improved via exposure to more tokens of the structures. There are parallels between this finding and the *mere exposure effect* (e.g., Zajonc, 1968), where it is found that liking of a particular stimulus increases as a function of exposure to that stimulus (see Luka & Barsalou, 2005, for a discussion of this point). Interestingly, Luka and Choi (2012) show that these adaptations can persist for a long time; even a week after exposure to the target structures, participants assessment of the sentences' grammaticality remained elevated. The long-lasting syntactic adaptation effect parallels the long-lasting perceptual learning effect reported by Kraljic and Samuel (2005). In both cases, the adaptations persisted even when participants were presented with more normative patterns of language experience between the training phase of the studies and the subsequent assessment of the adaptation effects.

Syntactic adaptation effects have also been demonstrated in language production. These demonstrations come mainly from studies exploring structural priming, or the tendency for speakers to repeat syntactic constructions across utterances (Bock, 1986; Pickering & Branigan, 1998; Pickering & Ferreira, 2008). For example, a person who has just produced a double object dative (DO; *The boy gave the girl a valentine*) is more likely to subsequently produce a double object to describe another transfer event (*The teacher sent the students a note*) than to produce a prepositional object dative (PO; *The teacher sent a note to the students*) to describe the same event. Hartsuiker and Kolk (1998) were among the first to report long-range adaptations within a structural priming paradigm. They elicited production of dative constructions in Dutch, and found that repeated production of datives over the course of the experiment led to higher rates of usage for those constructions at the end of the experiment compared to the beginning of the experiment. Hartsuiker and Westenberg (2000) report a similar finding in an experiment examining priming of the ordering of auxiliary verbs and past participles. They also report that the accumulation of priming across the course of the experiment was stronger for the less-preferred word orderings, providing another example of the inverse frequency effect.

To better understand the syntactic adaptions that occur across the production of multiple utterances, Kaschak and colleagues (Kaschak, Loney & Borreggine, 2006; Kaschak, 2007; Kaschak, Kutta & Jones, 2011) followed up on these initial reports by systematically manipulating the production of DO and PO dative constructions. In the first phase of these experiments, participants are induced to produce a certain proportion of DO and PO constructions (ranging from 100% DO constructions to 100% PO constructions). In the second phase, participants are given the freedom to choose the DO or PO construction in their productions. These studies show that participants are sensitive to the relative frequency with which they have produced each construction within the experiment. As the initial training phase of the experiment moves from being 100% DO to 100% PO, production of the DO construction declines (Kaschak, 2007; Jaeger & Snider, 2008). These studies also show an inverse frequency effect, with stronger adaptations in behavior being shown when participants are biased toward the lower-frequency PO construction than when they are biased toward the higher-frequency DO construction (e.g., Kaschak, Kutta & Jones, 2011; Jaeger & Snider, 2008).

Speakers are not only sensitive to how frequently they produce particular syntactic constructions, they are also sensitive to how frequently individual verbs are used within those constructions. Coyle and Kaschak (2008) held the frequency of producing DO and PO constructions constant across participants who produced each construction an equal number of times throughout the experiment. But Coyle and Kaschak (2008) also assigned individual verbs to appear only in one construction or the other (e.g., *give* would appear only in the DO, and *send* would appear only in the PO). Subsequent productions involving the target verbs showed that participants were sensitive to this bias – that is, participants were more likely to use the DO construction with verbs that had been biased toward the DO construction, and more likely to use the PO construction with verbs that had been biased toward the PO construction. Taken together, this set of results suggests that language producers are sensitive to the rates of production for given constructions within the confines of an experiment, and that their linguistic choices are shaped by this information.

As is the case in the grammaticality judgment experiments reported by Luka and Choi (2012), the syntactic adaptations that arise in language production experiments seem to be long lasting. Kaschak, Kutta and Schatschneider (2011) replicated the design of Kaschak (2007), in which participants were first biased toward either the DO or PO construction and are then given the freedom to choose either construction in generating subsequent productions. In this study, the two phases of the experiment were separated by one week. The results were clear: the syntactic adaptation that was produced in the first phase of the study was still present a week later. Kaschak, Kutta and Coyle (in press) extended this finding by investigating whether the adaptations that occur in the training phases of these studies transfer across language production tasks (e.g., a written stem completion task versus a picture description task) and whether the transfer would be similar when the tasks occurred in the same session or were separated by a week. The results suggest that syntactic adaptations transfer across task within the same session, but not when separated by a week. Syntactic adaptations were seen after a delay of a week only when the same language production task was used in both sessions. Kaschak et al. (in press) interpret these findings to suggest that the processing that goes into producing sentences -- the task demands of completing a sentence stem ,or describing a picture -- are an important part of what is remembered from a particular episode of language production. Thus, the match between the circumstances of production during the establishment of the syntactic adaptation and during the assessment of that adaptation will determine in part how strongly the adaptation effect is observed.. The overall pattern observed here is consistent with findings from the memory literature, particularly demonstrations that the importance of matching encoding and retrieval conditions for memory performance increases as the delay between encoding and retrieval increases (e.g., Read & Craik, 1995).

The literature reviewed above makes the case that syntactic representations continue to change with experience. Syntactic adaptations most likely occur very quickly, requiring only a small number of exposure sentences. Kaschak and Glenberg's (2004) participants learned the *needs* construction after 10 training sentences, and Kaschak et al.'s (2006) language production experiment produced strong adaptation effects with 10 training sentences. Syntactic adaptations are quite durable, persisting for at least a week. Syntactic adaptations are also sensitive to trial-by-trial changes across an experiment. Kaschak, Kutta and Jones (2011) found that beyond the general adaptation effects that occurred within their experiment, the immediate context -- whether a participant had produced one or more DO or PO constructions on the immediately preceding trials -- was a strong predictor of syntactic choice. Kaschak et al. (in press) and Kaschak and Glenberg (2004) discuss at length the ways that the syntactic adaptations that were observed in their studies fit with the larger body of studies concerning learning and memory, and how their findings are consistent with patterns that have been observed across many paradigms that have been used in the memory literature.

One issue that deserves additional comment is the presence of inverse frequency effects in many of the studies reported here. The finding that lower-frequency structures get more of a boost from exposure during training is interesting in that it represents a possible explanation for why low frequency options do not disappear from languages entirely. Repeated exposure to the higher-frequency syntactic choices in studies such as these does not seem to increase rates of usage for those choices too much above the baseline (see Reitter et al., 2011; Kaschak, Kutta & Jones, 2011), suggesting why higher-frequency choices do not snowball and push lower-frequency choices out of the picture. In contrast, use of the lower-frequency choice does produce a change in rate for that construction, thus serving to strengthen the place of that choice in the language. Frequency-sensitive learning of the sort described here is characteristic of connectionist models (e.g., Chang et al., 2006), providing another indication that general-purpose learning mechanisms may underlie patterns of language use.

3. Phonological Adaptations

A primary obstacle faced during the processing of speech is the amount of variability that is present in the input. The acoustic properties of a given word or speech sound can vary across speakers, and can vary within a single speaker across time. This is a recurrent problem for language users, as we are constantly faced with sub-optimal listening conditions (e.g., noisy rooms), speakers with unfamiliar dialects and speech patterns, and other sources of variability. The question of how listeners "hear through" this variability to perceive speech accurately has driven a good deal of research into speech perception over the last several decades. Early efforts to address this question focused largely on the idea that listeners have invariant, abstract representations of speech sounds, and that the variability present in the input is somehow normalized to the abstract representations (e.g., Liberman, Cooper, Shankweiler & Studdert-Kennedy, 1967; Kuhl, 1991). In short, the variability caused by differences in speakers, listening conditions, and so on, is stripped away during the perceptual process and recognition of speech sounds in terms of the stable underlying phonetic representations of one's language could proceed. This approach to speech perception fits within the general suggestion that linguistic representations become relatively stable after a certain point during one's formative years.

The idea that abstract phonetic representations are stable through adulthood, and are not changed by exposure to different sources of variability (such as having a conversation with someone with an unfamiliar dialect), can be called into question based on at least two sets of data. First, a number of studies in sociolinguistics have demonstrated that shifting patterns of speech behavior in young adults is responsible for sound change within linguistic communities (see Labov, 2001, for an extensive treatment of this issue). It seems plausible that these changes in production are accompanied by changes in the underlying perceptual representation of the sounds in question. Second, and more germane to the thrust of this chapter, a series of recent studies has documented the adjustments in perceptual representations that occur when listeners are exposed to different varieties of speech input (e.g., Kraljic & Samuel, 2005; Kraljic & Samuel, 2011; Sumner & Samuel, 2009; Norris, McQueen & Cutler, 2003). These studies fit within a growing body of literature (e.g., Nygaard & Pisoni, 1998; Bradlow & Bent, 2003; Trude & Brown-Schmidt, 2011) suggesting that speaker variability and other such "noise" in the speech signal may be more integral to construction of speech representations than previously thought.

Kraljic and Samuel (2005) conducted a series of experiments in which participants were exposed to normative /s/ or /sh/ sounds, or to sounds that were ambiguous, being somewhere between /s/ and /sh/. Participants performed an auditory lexical decision task in which ambiguous /s/-/sh/ sounds were heard. Previous work (Norris et al., 2003) had shown that lexical information would be used as the basis for deciding whether the ambiguous sound was an /s/ or /sh/. For example, an ambiguous sound heard in "eraser" would be perceived as an /s/, but the same sound heard in "official" would be perceived as /sh/. Subsequent to the lexical decision task, participants were tested with a range of sounds on the /s/-/sh/ continuum and indicated whether the sound was more like /s/ or /sh/. Consistent with previous demonstrations that listeners can adjust to the features of the speech that they are hearing (e.g., Norris et al., 2003; Bradlow & Bent, 2003; Maye, Aslin & Tanenhaus, 2008), Kraljic and Samuel (2005) found a perceptual learning effect: When the lexical decision task involved hearing ambiguous /s/-/sh/ sounds in places where an /sh/ would normally appear, participants were more likely to hear an ambiguous test sound as an /sh/ than as an /s/ (and vice versa for participants who heard the ambiguous sounds where an /s/ would normally appear during the lexical decision task). Interestingly, the perceptual learning effect persisted across time. There was no difference in the size of the perceptual adaptation effect between a group of participants who were given the /s/-/sh/ discrimination test immediately after the lexical decision training task and a group of participants who were given the discrimination task after performing a silent visual discrimination task for 25 minutes. Subsequent experiments showed that the perceptual learning effect persisted across time even when participants were presented with unambiguous "correcting" productions of /s/ and /sh/ from the same speaker that had produced the lexical decision items between the initial training phase and the test phase. The perceptual learning effect appears to be quite robust.

A further issue regarding the perceptual learning effect described by Kraljic and Samuel (2005; Norris et al., 2003; Maye et al., 2008) is that of speaker specificity: Is the learning specific to individual speakers, or does it generalize across speakers? The answer to this question is that the degree of generalization appears to depend on the particular contrast that is used for the perceptual learning study. Kraljic and Samuel (2007) performed two learning experiments, one employing a contrast between stop consonants (/d/ and /t/) and one employing a contrast between fricatives (/s/ and /sh/). Participants generalized their perceptual learning of the stop consonants across speakers, but did not do so for the fricatives. Kraljic and Samuel (2007) suggest that this difference is driven by the fact that fricatives are a useful source of speaker-specific information (i.e., variation in fricative production is diagnostic with respect to speaker identity), but stops are not. The perceptual learning effects will therefore extend as far as is licensed by the generality of the information presented in the particular phonetic contrast.

There are two things to note about the literature reviewed in the preceding paragraphs. First, the perceptual learning that has been demonstrated appears to interact with different levels of linguistic representation. Norris et al.'s (2003) initial demonstration of perceptual learning using the lexical decision task as a training paradigm showed that perceptual adaptation occurred only when the ambiguous speech sounds were presented within words; no learning occurred when the speech sounds were presented in non-words. This suggests that lexical representations play a role in the adaptation process. Beyond this, Kraljic and Samuel's (2007) data demonstrate that perceptual learning reflects sensitivity to particular dimensions of a given speech sound (e.g., voice onset time, or place of articulation). Idemaru and Holt (2011) propose that *dimension based statistical learning* (i.e., learning of the statistical regularities corresponding to particular dimensions of speech sounds) may be a mechanism that drives both long-range learning of phonological categories and the comparatively shorter-range learning demonstrated in experiments such as those reported by Norris et al. (2003) and Kraljic and Samuel (2005). Second, Kraljic and Samuel's (2007) finding that learning of contrasts that contain speaker-specific information generalizes differently than learning of contrasts without speaker-specific information suggests that learners are sensitive to the dimensions of speech sounds on which speakers differ, and this information is used as the speech perception system adapts to individual speakers. Given that adapting to individual speakers is a valuable skill for listeners, it is perhaps unsurprising that listeners would be sensitive to the dimensions of speech that should be attended to for accomplishing that adaptation.

Adaptation to individual speakers functions to shape phonological representations and facilitate speech perception. There is also evidence that adaptation to individual speakers can have consequences for language comprehension. Geiselman and Bellezza (1976, 1977; see also van Berkum, van den Brink, Tesink, Kos & Hagoort, 2008) proposed that listeners use acoustic information to recover information that is likely to be true of the speaker, and that this information plays a role in generating an interpretation of the linguistic input. As one example, van Berkum (2008) asked participants to listen to sentences such as, "If I only looked like Britney Spears," or "I have a large tattoo on my back." Measurement of event-related brain responses indicated that participants rapidly noted the incongruity when the voice characteristics of the speaker did not match the content of the sentence (e.g., the "Britney Spears" sentence being spoken by a male, or the "tattoo" sentence being spoken by someone with a refined upper-class accent). Speaker identity was rapidly taken into account when generating an interpretation of the sentences. Goldinger (1996, 1998; see also Church & Schacter, 1994) demonstrated the role of speaker information in memory performance. When participants are given a running old/new distinction task (wherein they must decide whether each word presented to them is "old," i.e., a repeated word from the list, or "new"), the odds of a participant correctly noting that a word is repeated are increased when the second token of the word is produced by the same speaker who produced the first token of the word. Nygaard and Pisoni (1998) further showed that speech perception performance in sub-optimal conditions (e.g., when listening to speech under noisy conditions) is improved when the listener has prior experience listening to that speaker.

More recent studies employing the visual world paradigm pioneered by Tanenhaus and colleagues (e.g., Tanenhaus, Spivey-Knowlton, Eberhard & Sedivy, 1995) have demonstrated that speaker information is used to guide speech perception and language processing from the very earliest stages of processing. For example, Trude and Brown-Schmidt (2011) presented participants with visual displays containing pictures of a target word such as *back* as well as pictures of a phonological distractor such as *bag*. In the visual world paradigm, the participants' eye position is monitored from the onset of the target word (back). The questions of interest in this paradigm are a) how often, and how far into the spoken target word, do the participant's eyes fixate on the distractor word (which begins the same as the target word, and is disambiguated from the target word at some point after the onset of the speech stimulus), and b) which variables affect the degree to which participants fixate on the distractor item. Trude and Brown-Schmidt (2011) found that speaker-based information was likely accessed at the very onset of the presentation of the target word, and that this information was immediately used to determine the identity of the word in question. Using a similar eye-tracking method, Creel & Tumlin (2011) confirm the finding that speaker-based information is accessed almost immediately upon hearing speech input, and that this information is rapidly deployed in the service of language comprehension.

Thus far, we have observed that perceptual learning occurs quite readily in listeners, that the learning process is sensitive to both low-level dimensions of speech sounds and higher-level lexical and semantic representations, and that the changes that result from perceptual learning are a durable component of the memory traces left by experiences with a given set of speech input. An important next step will be to explicate the exact nature of the memory mechanisms that are at work in these studies. Kraljic and Samuel (2011) begin to tackle this issue in a set of experiments that explore conditions under which perceptual learning had previously been found to be blocked: when the learner first heard the speaker produce standard tokens of a speech sound before producing the ambiguous variants of that sound, and when the learner saw the speaker producing the ambiguous variants of the sound with a pen in his or her mouth. Kraljic, Samuel and Brennan (2008) suggested that the blocking of perceptual learning was due to the learner making a detailed representation of particular talkers, and that variability that was taken as external to the speaker (i.e., speaking with a pen in one's mouth would produce variance in the speech sounds that are not typical of the speaker) was excluded from this representation of the speaker. Upon further study, Kraljic and Samuel (2011) proposed that the normal and deviant productions heard from a given speaker result in the construction of distinct phonological representations. That is, rather than there being a single model of a speaker, there may be multiple representations of a person's speech corresponding to the different types of speech episodes (e.g., pen-in-mouth vs. no pen) that are encountered. Kraljic and Samuel (2011) see an affinity between their approach and other work showing that perceptual representations have an episodic character (e.g., Goldinger, 1996; 1998).

The preceding paragraphs have suggested learning effects in the perception and comprehension of language. Learning effects have also been demonstrated in language production. These studies employ tasks to show that listeners can learn new phonotactic constraints. Dell, Reed, Adams, and Meyer (2000) asked participants to produce a string of nonsense syllables, for which a novel rule structure defined which phonemes could appear in the onset and coda positions. Participants readily learned these new phonotactic constraints. With a bit more difficulty, speakers can learn second-order phonotactic constraints (e.g., /k/ can only appear as on onset when /i/ is the vowel) under the same sort of training conditions (Warker & Dell, 2006). Thus, it appears that individuals are capable of adapting their perception and production of speech sounds on multiple layers of representation.

The following picture emerges when we consider perceptual learning in the speech domain. Learning happens rapidly. A relatively small amount of exposure is all that is required for listeners to adapt to the distinctive features presented by a new speaker. The fact that perceptual representations can shift so quickly underscores the dynamic nature of the speech perception system and highlights the more general claim that linguistic representations are in a constant state of flux. Indeed, Tuller, Case, Ding and Kelso (1994) demonstrated that categorization of ambiguous speech sounds of the sort used in the perceptual learning studies discussed here is affected by the trial-to-trial structure of the experiment. Categorization of speech sounds is affected not only by training across the course of an experiment, but also by the events that have occurred on a shorter time scale, such as the last trial or two in the study. This sort of micro-level adaptation has been taken as the hallmark of a self-organizing dynamic system, and such adaptation has been seen in other domains, including a range of binary decision tasks (such as responding to yes/no questions) and speech production (e.g., Gilden, 2001; van Orden et al., 2003; Kello et al., 2008). Thus, the patterns that are observed in perceptual learning experiments involving speech accord with more general principles about how the human cognitive system organizes its behavior within a given context.

Perceptual learning happens quickly, and it also occurs in a contextually-sensitive manner. Listeners' boundaries between speech sounds (such as /s/ and /sh/) can be shifted after exposure to a speaker who produces deviant examples of those sounds. The new boundaries between speech sounds continue to affect perception of speech from that initial speaker even when the training and test phases of the experiment are separated by exposure to a speaker who produces more normative examples of the speech sounds in question. This speed and flexibility of learning, as well as the fact that the learning can be done in a contextually-specific manner (e.g., the learning is specific to the perception of a particular person's speech) adheres to the more general principles that have emerged from the memory literature over the past several decades. For example, Crowder (1993) discusses how specificity in representations is a foundational principle of memory performance. Models such as Hintzman's (1986) MINERVA provide a ready explanation for how perceptual learning of speech sounds for individual speakers could be maintained independently of speech sounds from other speakers. The basic idea is that aspects of a speaker's voice will serve as a memory cue that will resonate more strongly with prior experiences with that same speaker than it will resonate with experience with other speakers. Thus, the rapid recovery of speaker identity from minimal speech input (see Creel & Tumlin, 2011) biases the speech perception process such that it will draw most strongly on previous experience with that speaker when interpreting the current input.

Finally, Kraljic and Samuel (2007) and Idemaru and Holt (2011) argue that learning about speech sounds is dimension-based, meaning that listeners will be most sensitive to the aspects of a speech sound that provide the most useful information for distinguishing that sound from others and for distinguishing one speaker from another. This sort of nuance in learning appears to be widespread in tasks involving statistical learning. In a typical statistical learning task, participants are given input that is structured by statistical regularities. For example, participants might be presented with a sequence of shapes in which the likelihood of one shape following another is governed by pre-determined statistical patterns, such as "A is followed by B 60% of the time, and followed by C 40% of the time." Participants are later tested for their success in extracting the relevant regularities. Turk-Browne et al. (2005) demonstrate that the outcome of the statistical learning process is determined in part by the dimensions of the input set that participants attend to (see also Whittlesea & Brooks, 1988). It therefore appears that in many domains in which learning the probabilistic structure of the environment is important (including the domain of speech perception; Idemaru & Holt, 2011), learning which features of the environment to attend to is a key aspect of the learning process. To conclude this section of the paper, phonological representations undoubtedly remain adaptable to ongoing experience, and the nature of these adaptations fits with observations about learning and memory from a wide range of experimental paradigms.

It is important to note that many of the features that we have identified as characteristic of perceptual learning parallel the features we have identified as characteristic of syntactic adaptations. In both cases, the adaptations occur quickly, are long lasting, are at least somewhat context specific, and seem to follow general principles of learning and memory. The similarities in perceptual learning, syntactic adaptation, and studies of learning and memory help to make the case that language is learned and processed using general-purpose cognitive mechanisms (and not language-specific processing mechanisms).

4. What Kind of Learning System?

We now turn to consider the nature of the learning system that is implicated in phonological and syntactic adaptations. There is a clear affinity between the effects that are discussed in this chapter and effects seen in other research paradigms in which participants adapt to the probabilistic structure of the input that they receive throughout the experiment. For example, participants are able to learn the rules that are used to generate letter strings such as AKTTYKST by keeping track of the probability with which certain letters are followed by other letters (e.g., Reber, 1993). Children are able to use the transitional probabilities between syllables (such as the likelihood of /be/ preceding /bi/, as in *baby)* to find words in a fluent stream of speech (e.g., Saffran, Aslin & Newport, 1996; Thiessen & Saffran, 2003). In addition, adults are able to use the statistical regularities in the location of particular objects that appear in visual displays to guide their eye movements as they search for target items on a computer screen (e.g., Jones & Kaschak, 2012). Many of these effects have been taken to be examples of implicit learning (see Perruchet & Pacton, 2006), and the phonological and syntactic adaptation effects that we have considered display many of the hallmarks of implicit learning. For example, the adaptation effects occur outside the participants' awareness (see Ferreira et al., 2008, for a demonstration of syntactic priming in anterograde amnesiacs); the effects are sensitive to the probabilistic structure of the learning input; the effects persist over long stretches of time (see Allen & Reber, 1980, for demonstrations of very long-term persistence of implicit learning), and the persistence of these effects over longer periods of time seems to depend (at least in some cases) on the match between the initial conditions of learning and the later test tasks (see Kolers, 1976, for a demonstration of this within a procedural learning paradigm).

It is sensible that adaptations to linguistic representations should be driven by the systems responsible for implicit learning. Given the real-time speed with which language is produced and comprehended and the lack of awareness that most of us have about the linguistic choices that we make at any given moment, it seems unlikely that explicit or conscious processes would be an ideal candidate to explain how the participants in these experiments are adapting their behavior to the input that they receive.

There is an appeal to connectionist models when considering linguistic adaptation effects, as these approaches demonstrate very nicely how encoding linguistic knowledge directly within processing mechanisms allows for a general degree of stability in the representations (over millions of utterances produced and comprehended, stable patterns will emerge in the model's behavior) while also allowing for the possibility of continued change (since the learning mechanism of the model is continually fine-tuning the representations based on ongoing experience; Chang, Dell & Bock, 2006). Although implicit learning (perhaps as implemented in a connectionist model) is likely to be a part of the story in explaining linguistic adaptations, it is clear that we have a ways to go before we have a complete picture of how linguistic adaptations work. For example, although we are often largely unaware of our patterns of language use, there are situations where we are conscious of the choices that we are making. Furthermore, there is reason to believe that explicit memory process may contribute to adaptations such as structural priming under certain conditions (e.g., Hartsuiker et al., 2008). It may therefore be important to consider the role of more conscious and explicit processes in a broader range of linguistic adaptations. Indeed, there is reason to believe that "implicit" learning processes may be more active and attention-driven (i.e., subject to influence by conscious and explicit processes) than originally believed (e.g., Perruchet & Vinter, 2002; Turk-Browne et al., 2005). Finally, it seems clear that although participants' behavior can be altered (sometimes quite strongly) within these experiments, their linguistic systems are not completely unhinged. An important step in developing models of linguistic adaptations will be to find ways to model the at times strong linguistic adaptation effects as a local, contextual event within the structure of a broader and more stable model of linguistic performance (as opposed to simply modeling the effects on one particular study).

Another factor that needs to be considered when thinking about a theoretical account of phonological and syntactic adaptations is that language use is inherently social (Clark, 1996). There are many examples of adaptations of linguistic behavior being driven by social factors. Giles, Coupland, and Coupland (1991; Ireland et al., 2011) discuss how interlocutors often align their linguistic behavior as a means of signaling affiliation. Indeed, observations of linguistic alignment are part of a larger body of evidence suggesting that alignment between individuals helps to build social bonds

(Chartrand & Bargh, 1999). Labov (2001) discusses how adaptations between speakers in a community (and, broader patterns of language change) are affected by social factors such as race and gender. For example, Labov's (2001) study of sound change in Philadelphia suggests that sound changes are driven by female speakers. The more advanced forms of the sound change are therefore marked as characteristic of "female" speech, and this causes male speakers to move away from these more advanced forms. Coyle and Kaschak (2012) demonstrated that the likelihood of a male conversant matching the syntactic structures of a female conversant was affected by the timing of the interaction within the female's menstrual cycle: During periods of higher fertility, structural matching decreased.

The adaptation of linguistic behavior to linguistic surroundings may be somewhat mechanical in the studies reviewed in this chapter, but it is just as clear that this kind of adaptation can be deployed (even unconsciously) to serve a range of social functions (e.g., Ireland & Pennebaker, 2010). It should be noted that although linguistic adaptations and alignment generally occur on an unconscious level, we do not wish to claim that adjustments of one's linguistic behavior is always unconscious. There are clearly cases in which a speaker may consciously change the way they talk to adjust to their conversational partner (e.g., a person speaks differently to a young child than to their boss). Developing a full understanding of the processes through which the linguistic system changes over time will require not only specifying the implicit and explicit memory processes that operate when linguistic stimuli are processed, but also considering the ways that representations of explicit and implicit social motivations interface with the processing of language.

5. Concluding Remarks

We began this chapter by asking why languages are shaped the way they are. From a functionalist perspective, the answer to this question is that general cognitive processes of perception, learning, and memory put constraints on the ways that language can be learned, processed, and changed. When played out over thousands of generations, these constraints have fine-tuned the languages of the world so that they employ just a small fraction of the possible design features that could be used (Christiansen & Chater, 2008). The functionalist view takes the perspective that the handling of language within the cognitive system is not unique or special; language is handled just as other domains of knowledge are handled, and is subject to the same general principles of learning, memory, and processing as is everything else.

Throughout this chapter, we have attempted to demonstrate the value of the functionalist perspective by reviewing empirical demonstrations of phonological and syntactic adaptation effects. We have argued that phonological and syntactic adaptations are cases of implicit learning within the cognitive systems responsible for processing language and that phonological and syntactic adaptations follow the principles of implicit and procedural learning demonstrated in other domains. That is, there is nothing unique about the effects that occur within the linguistic domain. An important future direction in developing this literature will be to understand how what we learn about linguistic adaptations on the psycholinguistic level (as seen in the studies here) can be used to understand how languages change across time and communities. This effort will no doubt require integrating psycholinguistic, social psychological, and sociolinguistic approaches (see Pickering & Garrod, 2004, for a discussion). The current spate of studies looking at the evolution of communication systems within the lab (e.g., Fay et al., 2010; Kirby et al., 2008) provide an interesting template for how this may be done. For example, Kirby et al. (2008) discuss studies in which transmission of language across generations is mimicked by employing chains of learners where the output of one participant's learning within an experimental task is then used as the training input for the next learner in the chain. Pressing along this line, we will be in a better position to understand one of the basic tenets of Christiansen and Chater's (2008) approach, namely that it is the properties of human cognition, not an innate universal grammar, that have played a key role in shaping languages to be the way that they are.

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