Annual Review of Applied Linguistics (2001) **21**, 23 42. Printed in the USA.

2. APPRAISAL PSYCHOLOGY, NEUROBIOLOGY, AND LANGUAGE

John H. Schumann

This volume of *The Annual Review of Applied Linguistics* explores the connections between psychology and language. In the following chapter, I will show how a field that increasingly informs psychology can also inform the psychological issues that concern applied linguists. Neurobiology and psychology have become more closely integrated in recent years as evidenced by the emergence and development of such disciplinary interfaces as biopsychology and cognitive neuroscience. The recognition that psychological phenomena are subserved by the brain is widely accepted; via developments in neuroimaging technology, the brain is becoming amenable to direct psychological investigation. In this chapter, I examine brain mechanisms that are involved in second language acquisition motivation, in cognitive/motor exploratory activity in learning, and in decision-making aspects of pragmatics in language use.

The Neurobiological Circuitry

There is a neural system in the brain that appears to subserve two important functions stimulus appraisal and social cognition. Stimulus appraisal involves the assessment of the emotional and motivational relevance of agents, events, and objects encountered by an individual in its environment (Leventhal & Scherer, 1987; Ortony, Clore, & Collins, 1988; Scherer, 1999). Such appraisals generate tendencies to undertake mental and motor activity in relation to given stimuli (Frijda, 1987). Social cognition is the ability to make hypotheses about the intentions and dispositions of others (Brothers, 1990) and to reason about personal and social issues (Damasio, 1994).

In this chapter, I propose that the confluence of stimulus appraisal and social cognition that is effected by this neural system has important implications for language and learning theories. I describe the anatomy and functions of this neural system, and then I propose to show how it may operate in motivation for SLA (Schumann, 1997) and how in , conjunction with some additional circuits it may operate in generating mental and motor activity for learning generally (Schumann, in press-a, in press-b). Finally, I will argue that the major components of this system also subserve decision-making in language pragmatics (Schumann, 1990).

The mechanism involved in this neural system consists of the amygdala (located in the temporal lobes) and the orbitofrontal cortex (located in the front of the brain above the orbits of the eyes). These areas connect to systems in the body proper i.e., the autonomic nervous system (responsible for fight or flight responses), the endocrine system (responsible for the regulation of hormones), and the musculoskeletal system (responsible for body position, tension, and movement) (Damasio, 1994; Schumann, 1997).

The Amygdala

The amygdala is an almond-shaped nuclear structure located in the anterior part of each temporal lobe. Much research on the amygdala has shown that it responds to negative stimuli, particularly to stimuli that are threatening or frightening. For example, monkeys who have had their amygdalas removed lose their natural fear of snakes (Klüver & Bucy, 1939). Similarly, rats are usually wary of new objects in their environment, but when their amygdalas have been ablated, this neophobia is vastly diminished (Rolls, 1995). Likewise, rats can be conditioned to fear a tone because it will be followed by a foot shock. If their amygdalas are destroyed, they will not form an association between the tone and the shock, and their fear conditioning will be impaired (LeDoux, 1996).

In humans, the destruction of both amygdalas is rare, but several cases are currently being studied. One such patient has been shown to have deficits in recognizing fear and blended emotion in other peoples faces (Adolphs, Tranel, Damasio, & Damasio, 1994). Another patient demonstrates impairment in matching pictures that depict emotions with the names of those emotions and in matching pairs of photographs that depict the same emotion. In addition, this patient has difficulty determining when and if someone is looking at her (Young, et al., 1995).

Moreover, patients exhibiting amygdala damage have been shown to judge as trustworthy and approachable pictures of faces of people whom normal subjects appraise as untrustworthy and unapproachable. When judging pictures of people whose faces are generally deemed approachable and trustworthy by normal subjects, however, the amygdala-damaged patients do make similar judgments (Adolphs, Tranel, &

Damasio, 1998). Patients with bilateral amygdala damage have also been shown to have a positive bias in evaluating pictures (line drawings, landscapes, spheres, and Mondrians) which normals evaluated negatively (Adolphs & Tranel, 1999).

In another experiment, normal controls and a subject with amygdala damage were shown a video in which three geometric shapes moved on a screen. When asked what they had observed, the normal subjects interpreted the action of the figures in social terms, imbuing them with goals and desires, etc. The subject with amygdala damage provided a strictly geometric description of the action, without attributing mental states to the figures (Heberlein et al., 1998, cited in Adolphs, 1999). An amygdala-damaged patient was also shown to be able to recognize valence (pleasantness or unpleasantness) in facial expressions and in descriptions of various situations, but was impaired in comparison to controls in rating the arousal level (energy, wakefulness) of a person with a particular facial expression or of a person described as having a particular experience. This patient gave low arousal ratings for emotions with negative valence, and, in comparison to controls, provided low ratings for stimuli representing fear and anger (Adolphs, Russell, & Tranel, 1999).

Normal subjects in a Stroop test[1] showed more amygdala activity as measured by positron emission tomography (PET) when naming the color of threat words (e.g. *persecute, assassinate, failure, blame*) than when naming the color of neutral words (e.g. *review, custom, bowl, pen, journey*) (Isenberg et al., 1999). In comparison to normal controls, a subject with bilateral amygdala damage had difficulty identifying emotions (*happy, angry, sad*) in sentences that were read to her. This patient was also impaired in deciding whether pairs of sentences were read by the same or different people and performed at chance level in deciding whether a sentence read to her was a statement, a question, or an exclamation. On a task in which words were read with intonation indicating a particular emotion, the patient had great difficulty identifying fear; she also had problems distinguishing happy and sad intonations. Finally, when asked to identify the emotions in nonverbal sounds (grunts, growls, etc.), she performed poorly in identifying fear and anger (Scott et al., 1997).

In a recent experiment, non-amygdala damaged subjects showed higher regional cerebral blood flow (rCBF) in the amygdalas and hippocampal areas for the observation of both pleasant and aversive stimuli than for interesting but emotionally neutral stimuli. When the same subjects were tested four weeks later, they had higher recognition memory for the emotionally pleasant and aversive pictures than for the emotionally neutral stimuli (Hamann, Ely, Grafton, & Kilts, 1999). Researchers (McGaugh, Roozendaal, & Cahill, 2000) report that the interaction of various neuromodulators (such as epinephrine, glucocorticoids, opoid peptides, and GABA, an inhibitory neurotransmitter) in the amygdala (basolateral area) enhances the formation of long-term declarative memory elsewhere in the brain for both positive and aversive emotional events. Citing Cahill et al. (1996), they report a PET study which showed a correlation between subjects glucose metabolic rate while watching emotional videos and while recalling the incidents in these videos when tested three weeks later.

Finally, Adolphs (1999), citing Bradley, Pety, and Lang (1992) and Mealy, Daood, and Krage (1996), describes research which shows that emotionally and socially relevant stimuli are remembered better by normals than they are by patients with bilateral amygdala damage (Adolphs, Cahill, Schul, & Babinsky, 1997).

The amygdala research reviewed above indicates that this set of nuclei in the brain is involved in the appraisal of the emotional relevance of pleasant and aversive stimuli, visual and auditory stimuli, social stimuli (such as faces, voices, and arousal levels), nonsocial stimuli (geometric shapes, pictures), and the content and prosody of verbal stimuli. Furthermore, the amygdala appears to be particularly sensitive to stimuli that represent fear or threat. Finally, the amygdala seems to be involved in the formation of long-term memories of emotional stimuli.

The Orbitofrontal Cortex (OFC)

The orbitofrontal cortex (or ventromedial prefrontal cortex) is located in the front of the brain, above the orbits of the eyes. This region of the brain appears to be involved in the acquisition of knowledge about social conventions as well as in the control of behavior related to those conventions. In addition, the OFC appears to subserve reasoning about social, moral, and personal issues. In this latter role, it helps to bias an individual s decision-making toward a subset of alternatives in reasoning about complex social, moral, or personal situations, through its connections to the peripheral nervous system (the autonomic nervous system, the endocrine system, and the musculoskeletal system) (Anderson, Bechara, Damasio, Tranel, & Damasio, 1999; Bechara, Damasio, & Damasio, 2000; Damasio, 1994).

The OFC also seems to be involved in learning and in tracking reward contingencies. It provides signals when a behavior ceases to be rewarding (Rolls, 2000) and thus prevents perseveration in unproductive and in counterproductive activities. Rolls (2000) also reports research indicating that the OFC is involved in recognizing and identifying the emotional qualities of others facial and vocal expressions and that different parts of the OFC are selectively responsive to pleasant touch, pain, taste, and smell.

People with OFC damage have been shown to ignore social conventions and to become rude, vulgar, and disrespectful. They appear unconcerned about their behaviors, even when those behaviors are harmful to themselves or others. They are unaffected or unresponsive to the consequences of their actions and thus are unembarrassed and unashamed by social, professional, and personal failures. They are frequently unable to keep goals in mind, they become distracted by local environmental stimuli, and they are inclined to continue activities even after those activities cease to be rewarding or productive (Adolphs, 1999; Bechara et al., 2000; Damasio, 1994). Yet, although adults with OFC damage have impaired social, personal, and emotional reasoning and behavior, they frequently have access to the declarative knowledge underpinning it. However, patients who incur OFC damage in early childhood seem to be unable to acquire the knowledge necessary for appropriate social and moral reasoning and decision-making (Anderson, et al., 1999). In addition, recent research (Denburg, 1999, cited in Bechara et al., 2000) indicates that some adults over 64 years of age perform on tests of personal decision making (see the gambling task below) in ways similar to OFC patients. This may indicate that, in some adults, the OFC may be subject to acquired impairments with increasing age.

An experiment involving a gambling task has been successful in demonstrating orbitofrontal deficits. In this experiment, subjects are asked to choose from four decks of cards, two of which generate high winnings and even higher losses. The other two decks produce smaller winnings and smaller losses which, in the long run, generate a larger amount of money. Normal subjects relatively quickly switch from the risky decks to the decks that generate smaller losses. OFC patients continue to select from the high-risk decks in spite of the repeated losses. Some of these patients even become consciously aware of the inevitable loss associated with the risky decks, but continue to choose from them, nevertheless. In addition, normal subjects develop anticipatory skin conductance responses (low levels of perspiration) that appear before choosing from a risky deck. The OFC patients, however, get no such signals from their autonomic nervous systems when they consider a high risk choice (Bechara et al., 2000). Thus, the OFC appears to be involved in the acquisition of information about social and personal behavior and in the ability to guide an individual in the regulation of that behavior.

The Body Proper

As mentioned earlier, the amygdala and the OFC have reciprocal connections to areas of the peripheral nervous system (which consists of the autonomic nervous system, the endocrine system, and the musculoskeletal system). Damasio (1994) proposes that the perception of stimuli generates a bodily state in the peripheral nervous system. The bodily state (called a *somatic marker*, from the Greek word *soma*, meaning body) is considered an emotion that is communicated back to the brain as a feeling. This feeling arises as a result of the juxtaposition of the ongoing perception of the current stimulus situation with stored images of the same or similar situations that have been encountered in the past. Such association is called a *dispositional representation*. The feeling is essentially an appraisal of the emotional and motivational relevance of the stimulus. This appraisal, in turn, provides information about whether a given stimulus is positive or negative, good or bad, and about whether it should be engaged or avoided. When stimulus situations have been frequently associated in the past with their emotional valence (as indicated by the presence of a somatic marker), they can become represented in the brain itself and no longer need processing in the peripheral nervous system.

From Stimulus Appraisal to Motivation

Although Damasio and his colleagues emphasize the role of the neural system discussed above (and, in particular, the OFC) in social reasoning and decision making, I would like to suggest that, at its most basic level, the mechanisms of this system subserve the individual s appraisal of the emotional valence and motivational relevance of stimuli. The process of stimulus appraisal has been studied by psychologists interested in emotion. These researchers believe that the perception of a stimulus or stimulus situation itself does not generate an emotion; rather, the construal by the individual of how the stimulus will affect him or her is what produces an emotional state (Leventhal & Scherer, 1997; Scherer, 1999). Appraisal psychologists have conducted extensive research to determine the criteria on which the assessments of stimulus situations are made, and Scherer (1988, 1999) finds that there is remarkable consistency across the dimensions proposed by the various researchers. The categories described below (by Scherer, 1984, and Leventhal & Scherer, 1987) provide a system that adequately reflects, at the psychological level, the workings of the biological mechanisms described above (see also Schumann, 1997).

Scherer (1984) identifies five appraisal dimensions i.e., novelty, pleasantness, goal or need significance, coping ability, and compatibility with self and social image. Novelty appraisal assesses whether a given stimulus is the same as previously encountered stimuli or whether it is new. Pleasantness appraisal is concerned with whether or not the experiencer finds a stimulus appealing, enjoyable, or pleasant in and of itself. Coping ability (or *coping potential)* is an appraisal by the individual of his or her ability to deal effectively with the physical, mental, and social demands of a stimulus or stimulus situation. Finally, self and social compatibility appraisal evaluates a stimulus with respect to the experiencer s view of his or her ideal self and with respect to the experiencer s perceived views of family, friends, and community.

Such stimulus appraisals generate tendencies to undertake mental and motor activity in relation to a stimulus. These tendencies may involve approach behavior, withdrawal or avoidance behaviors, or neutral behavior that maintains the organism s current relationship *vis à vis* the stimulus (Frijda, 1987; Frijda, Knipers, & ter Schure, 1989; Schumann, 1997).

Schumann (1997) notes that the questions used in motivation questionnaires in second language acquisition research actually elicit appraisals of objects, events, and agents related to the target language. On the basis of this observation, he argues that motivation may actually be *patterns of stimulus appraisal.* For example, Gardner (1985) uses the following questions, all of which evoke appraisals, in his Attitude and Motivation Test Battery:

French Canadians add a distinctive flavor to Canadian culture (Gardner, 1985, p. 178). This question assesses the appealingness, or *pleasantness*, of agents.

Studying French can be important to me because it will allow me to meet and converse with more varied people (Gardner, 1985, p. 179). This probe assesses *goal compatibility.*

Studying French can be important for me because other people will respect me more if I have a knowledge of a foreign language (Gardner, 1985, p. 179). This question elicits appraisals on the dimensions of *goal relevance* and *norm/self compatibility.*

I get nervous and confused when I am speaking in my French class (Gardner, 1985, p. 179). This probe generates appraisal on several dimensions: *coping potential, norm/self compatibility,* and *appealingness.*

Schumann (1997, in press) suggests that, as a system, the amygdala and orbitofrontal cortex, interacting with incoming signals from the body proper, may subserve stimulus appraisal in humans. In this system, the amygdala may operate in the appraisal of the basic pleasantness of stimuli and would certainly be involved in the assessment of threat and arousal and in determinations relating these stimuli to coping potential. Moreover, evidence from animal research (Rolls, 1995) indicates that the amygdala is sensitive to novelty. Amygdala-damaged patients difficulties with determining whether people are trustworthy and approachable would also affect their coping potential appraisals (Adolphs et al., 1998). The fact that amygdala patients positively evaluate pictures that normals appraise negatively also seems to indicate that the amygdala is involved in stimulus appraisal on the dimension of pleasantness.

Damasio (1994) and Schumann (1997) argue that the orbitofrontal cortex (OFC) subserves appraisals established during the lifetime of the individual through education, socialization, and experience. This contention is supported by the evidence that OFC patients who incur brain damage very early in life have diminished ability to acquire social rules, and that adults with OFC damage have deficits in implementing such rules, despite having acquired the prerequisite knowledge. Such difficulties certainly impact these patients stimulus appraisals made on the basis of self and social compatibility and appropriateness. Their problems in personal and social decision-making, as evidenced in the gambling experiments, indicate that the OFC participates in appraisals of *coping potential*. The fact the OFC patients have difficulty keeping goals in mind and perseverate in unrewarding behaviors indicates that the OFC is involved in appraisals of *goal relevance*. Finally, the fact that various areas of the OFC are sensitive to touch, taste, and smell (Rolls, 1999) suggests that it is just as intricately involved in appraisals of *pleasantness* and perhaps *novelty*.

From Appraisal to Behavior: Translating Motivation into Action

Learning requires a goal i.e., the desire to possess some knowledge or skill. This goal functions as a reward, and achieving it is perceived by the organism as pleasurable, reinforcing, or rewarding. It would appear that such goals are generated by positive appraisals of particular outcomes; in the case of learning, a positive appraisal by an individual of his or her having some particular knowledge or skill. This appraisal would be the equivalent of liking the idea of knowing something or the idea of being able to do something (Berridge & Robinson, 1998). But in order to achieve such goals, liking has to become wanting (*ibid.*), and activity has to be generated to reach the goal.

A potential *incentive motive* (or goal) functions as an environmental stimulus that is appraised positively and thus as something to be desired. Such a goal has to be maintained and translated into mental and/or motor activity for its achievement. The neural substrate supporting goal generation and maintenance (See Figure 1) appears to be a circuit consisting of the amygdala and the orbitofrontal cortex and includes dopaminergic innervation of two additional structures, the nucleus accumbens shell and the ventromedial ventral pallidum (Depue & Collins, 1999; Deutch, Bourdelais & Zahm, 1993; Heimer, Alheid & Zahm, 1993;

Kalivas, Churchill, & Klietnick, 1993; Mogensen, Brudzynski, Wu, & Yim, 1993; Schumann, 1997, in press- a; in press- b). The translation of the incentive motive, or goal, into behavior to achieve the goal is subserved by a circuit (See Figure 1) consisting of projections from the ventromedial ventral pallidum to the mediodorsal thalamus to the prefrontal cortex (area 32), back to the nucleus accumbens core to the dorsolateral ventral pallidum and then to the pedunculopontine nucleus, the brain stem motor nuclei, and the spinal cord (Deutch et al., 1993, Heimer et al., 1993; Kalivas et al., 1993; Mogensen et al., 1993; Schumann, 2001, in press; Skinner & Garcia-Rill, 1993).

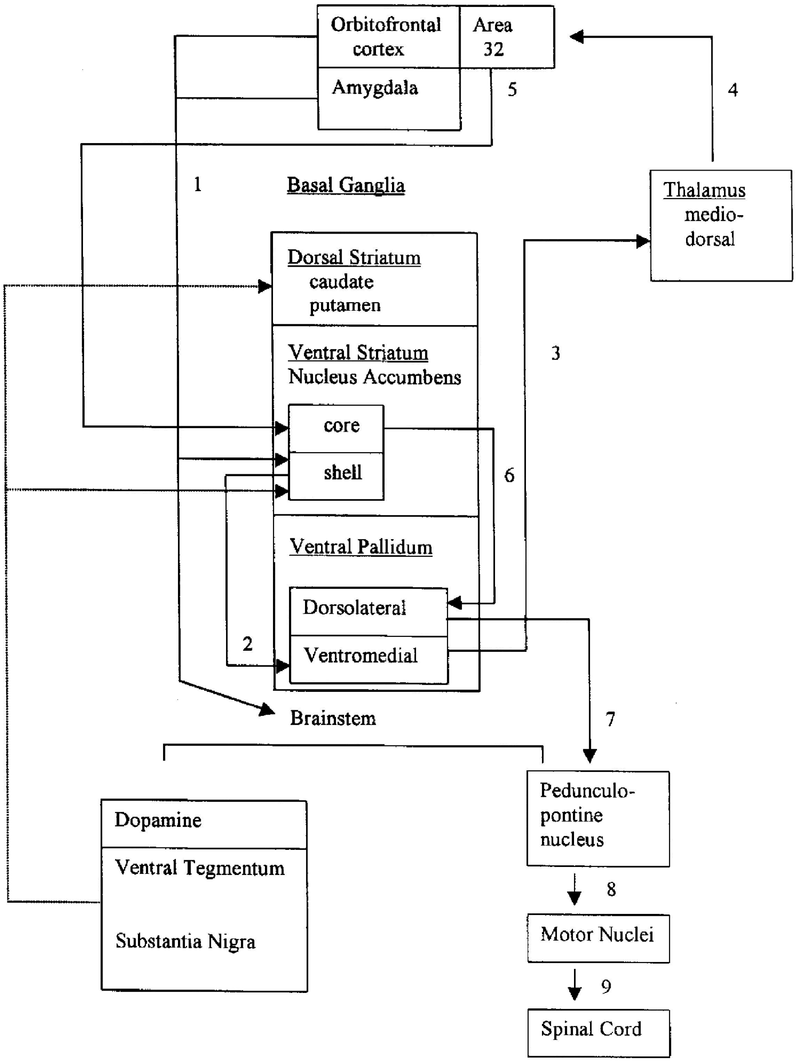

Figure 1: Mechanisms for stimulus appraisal, incentive motive/goal formation, and the translation of an incentive motive/goal into motor and mental behavior.

Schultz, Tremblay, and Hollerman (2000) have examined the responses of neurons in the orbitofrontal cortex, the dorsal and ventral striatum (i.e., the caudate, putamen, and nucleus accumbens), and in midbrain dopaminergic regions (the ventral tegmentum and the substantia nigra) that are responsive to stimuli related to reward processing. Each of these areas contains neurons that respond to reward, and that do so simultaneously; however, neurons in each area function in somewhat different ways.

The researchers discovered that monkey orbitofrontal neurons were activated by instructions that were predictive of reward (food or juice). These neurons were also active for a period just before the reward was supplied, and they spiked again after the monkey had consumed the reward. Orbitofrontal neurons were also sensitive to reward preferences, generating more activity for the preferred reward. Neurons in the striatum (STR) were activated when the animals received instructions that had been associated with reward. Some STR neurons also showed a long and gradually increasing activation between the instruction and a trigger. STR neurons also showed activation prior to or in expectation of reward (related to motor activity for getting the reward) and after consumption of the reward. Dopamine (DA) neurons were driven initially by unexpected reward and then by antecedent stimuli predicting the reward. These neurons also showed excitation during the perception of stimuli that elicit attention. Finally, when a predicted reward did not materialize, dopamine activity became depressed. Thus, in this system, neurons respond in expectation of reward during a period just before a predictable reward is delivered (OFC, STR), during musculoskeletal activity undertaken in expectation and preparation for reward (STR), to stimuli that predict reward (DA, some OFC, some STR), after rewards that are predictable and expected (OFC, STR), and after unpredicted rewards (OFC, DA). In addition, dopamine neurons show depressed activity when an anticipated reward fails to appear.

Berridge and Robinson (1998) report that rats exhibiting nearly 100 percent depletion of dopamine retain the ability to ascertain the pleasurable qualities of food stimuli, but that they lose the ability to make the necessary efforts to obtain and to consume such food. On the basis of this evidence, the researchers argue that dopamine is involved in wanting, but that it is not necessary for liking. They suggest that dopamine allows the organism to attribute *incentive salience* to environmental stimuli such that certain agents, events, or objects associated with previous reward (conditioned stimuli) become desirable and worthy of effort and engagement in their own right because of the expectation that they will lead to future reward. Stimuli that accrue such incentive salience are attractive and elicit approach i.e., exploratory behavior that can ultimately lead to reward or to the achievement of a goal. If, in future encounters, such stimuli generate a positive hedonic state (i.e., liking), then the incentive value will remain and will continue to elicit instrumental or appetitive behavior. If, however, future engagement with the stimuli do not produce a positive state, the stimuli (agents, events, and objects) will lose their incentive value.

Ikemoto and Panksepp (1999) argue that nucleus accumbens dopamine produces a flexible approach response system (p. 26). Rats and humans have some behaviors that are fixed habits; these fixed action patterns are either inherited or developed. In the face of certain stimuli, such habits have a strong tendency to produce fixed responses. The nucleus accumbens dopamine system, however, enables more flexible investigatory activity, potentially allowing stimuli to accrue incentive qualities signaling reward (e.g., achieving one s goal). Such signals are essentially go signals (Rolls, 1999), indicating to the organism that it should continue its activity i.e., continue mental and/or motor approach behaviors leading to food consumption or goal achievement.

Like Berridge et al. (1998), Ikemoto et al. (1999) note that the action of dopamine on the nucleus accumbens does not simply provide pleasure or euphoria in the way that sex or food consumption might. Rather, destruction of the nucleus accumbens does not decrease consummatory behaviors, but instead decreases exploratory activity antecedent to consumption. Ikemoto et al. suggest that the conscious experience of dopamine transmission in the nucleus accumbens might be described at the symbolic level as curiosity or interest or urge with the last phenomenological manifestation occurring just before consummation.

From this perspective, in a particular environment, nucleus accumbens dopamine can be seen as guiding the learner to respond in an adaptive way to environmental agents, actions, and objects that constitute incentive stimuli associated with reward. Ikemoto et al. (1999) argue that the nucleus accumbens dopamine system guides such appropriate behaviors until they become familiar and routine, at which point the behavior is off-loaded onto the striatal (caudate and putamen) habit system. Here it can be initiated and implemented automatically in the presence of the incentive stimuli, which are recognized by declarative memory. If, however, new stimuli are introduced within this context or if the individual moves into a new environment the nucleus accumbens dopamine system must again be engaged to facilitate recognition and acquisition of the incentive properties of the new stimuli.

Because familiar stimuli are less likely to generate nucleus accumbens dopamine transmission (Ikemoto et al., 1999), the dopamine mechanism fosters investigatory behaviors toward novel stimuli. These behaviors allow appraisal of the incentive value of novel stimuli; such appraisals, in turn, lead to either approach activity or to activity that will allow the organism to withdraw to safety.

Thus, ablation of the nucleus accumbens will disrupt reward (goal) seeking behaviors, but once the behaviors become routine (i.e., habits), lesioning the ventral striatum will not affect learned behaviors (Ikemoto et al., 1999). This generalization is further supported by research (ibid.) which shows that self-administration of alcohol by rats can be diminished by ablating the ventral striatum during the learning phase, but that once such behaviors become habit, destruction of the nucleus accumbens does not affect the rats reward seeking activities.

Several researchers have suggested that the ventral striatal dopaminergic system is a major component of the neural system that subserves foraging in animals and humans (Ikemoto et al., 1999; Montaque, Dayan, Pearson & Sejnowski, 1995; Robbins & Everitt, 1996). On the basis of this research, as well as much of the work reported in the current paper, Schumann (2001, in press) has suggested that learning may be a form of foraging, and that the motor and mental activity involved in foraging for knowledge and skill may be subserved largely by the same mechanisms as those underpinning foraging for food.

For example, a learner who has the goal of acquiring a second language must translate the incentive motive into motor and mental activity in order to engage with sources of target language input. In other words, the learner must discover incentive stimuli that will help him or her learn the language. Such incentive stimuli might be a class, a teacher, a language teaching method, approach or technique, a text, particular explanations, vocabulary, exercises, tests and other assessment instruments or procedures, fellow learners, target language speakers, the target language culture and, of course, tokens of the spoken and written language itself. All these stimuli are associated with the reward or the goal i.e., the acquisition of the second language. When the learner encounters them, they are appraised for their *novelty, goal relevance, coping challenges,* and their *compatibility with the learner s self and social image*.

If the learner perceives the incentive stimuli to be rewarding (i.e., if they facilitate her perception that she is acquiring the target language), we can hypothesize that her amygdala and orbitofrontal cortex are subserving those appraisals and that dopamine innervation of the striatum is also supporting the assessments (as well as the mental and physical activity that the learner expends in engaging those stimuli). In other words, the learner will be *motivated*. Contrarily, if certain stimuli related to the acquisition of the target language are *not* perceived as facilitating the goal/reward, the relevant negative appraisals will be made, dopamine activity will be suppressed, and the stimuli will be avoided. In this case, the learner will lose motivation and become *demotivated*. If such stimulus appraisals are sufficiently negative over a period of time, the learner may abandon her goal altogether.

Another example of learning as foraging can be seen in scholarly activity. A researcher may forage on a computer and locate references to several articles which he thinks might be relevant to a goal e.g., developing a model or a theory of a particular phenomenon. The researcher then forages in the library, locates the articles, photocopies them, and takes them to his home or office. In animals, such foraging activity frequently involves hoarding gathering food, not for immediate consumption, but for future use. (Ikemoto et al. [1999] report that rats with disrupted dopamine transmission or nucleus accumbens lesions will gather food and perhaps take it to another place to satisfy current hunger, but they will not collect it and move it to a new location for future consumption.) Similarly, a scholar s gathering of materials may also be viewed as hoarding items that predict future reward. We can thus hypothesize that the researcher s foraging for and hoarding of items which may be relevant to a scholarly goal is likewise guided by the nucleus accumbens dopamine system.

To expand upon our analogy, let s suppose that on the weekend the scholar chooses one of the foraged articles and begins to read it. If the article does indeed provide information perceived as useful for the research goal, it will be positively appraised and its source (the article) is likely to be represented in the researcher s declarative memory. Associations will be made with the title of the journal and with the names of the author(s) for future foraging and gathering. Reading the article constitutes exploratory/investigative behavior, behavior which we can again hypothesize is stimulated by the dopamine-nucleus accumbens mechanism (which may also potentiate further cognitive/motor foraging behaviors, such as underlining, taking notes, identifying references in the text for further investigation, etc.). Such activities mediate the acquisition of knowledge that will contribute to the scholar-forager s goal to develop his argument/model/theory.

Based on Ikemoto et al. s (1999) perspective, we might speculate that if the researcher s nucleus accumbens dopamine release were, for some reason, disrupted, he might nevertheless engage in mental foraging activities but with less focus and less flexibility, because he might not as readily recognize pieces of information as incentive stimuli i.e., as relevant to his goal. In fact, given sufficient dopamine depletion, the researcher might abandon foraging (such as would be constituted by his reading of the articles) altogether.

Another scenario one not involving learning might facilitate speculation about how the nucleus accumbens dopamine mechanism helps humans identify stimuli incorporating incentive information that can be used to accomplish a goal. When traveling someplace unfamiliar by car, one frequently consults a map and plots a route from one s home to the desired location. On the map, relevant streets, intersections, parks, monuments, buildings, street numbers, etc. will be identified. These landmarks constitute incentive stimuli. During the trip, when they are recognized in the actual environment, they will constitute predictors of reward and we can speculate that their recognition will stimulate dopamine release. Essentially, such positively valenced stimuli act as go signals (Rolls, 1999) that indicate that the traveler is on the right track and should continue. Suppose that, on the other hand, the expected landmarks fail to appear as the driver attempts to navigate his way. If this were to occur, we would speculate that the driver s dopamine activity would become depressed, acting now as a signal to do something different, such as to examine the map again or to ask someone for directions.

What I have suggested so far is that a neurobiological circuit consisting of the amygdala, the orbitofrontal cortex, and the body proper along with dopamine innervation of the striatum constitutes the brain mechanism for stimulus appraisal, motivation, and the cognitive/motor activities that are involved in identifying and in engaging stimuli that will lead to the acquisition of desired knowledge or skills. The model proposed here provides a mechanism which guides learners efforts to locate and interact with incentive stimuli that facilitate goal achievement. A future development of this model will be an account of how the information contained in

the stimuli engaged during motor and mental foraging becomes encoded in the brain.

Decision-Making in Language Pragmatics

The major components of the stimulus appraisal system (amygdala, orbitofrontal cortex, and body proper) also seem to be important neural structures for social cognition (Adolphs, 1999b; Brothers, 1990, 1997; Schumann, 1997, 1999). In addition, Damasio (1994), Anderson et al. (1999), and Bechara et al. (2000) show that this system (and especially the orbitofrontal cortex) is important in reasoning and in decision-making about social and personal issues. Schumann (1999) argues that such reasoning and decision-making as well as the hypothesizing about the intentions and dispositions of others is done on an ongoing basis during the course of real-time language-use pragmatics.[2]

I have argued above that the amygdala is involved in recognizing and assessing novel stimuli; in detecting emotions (especially fear) in peoples facial expressions; in determining the eye gaze of interlocutors; in judging the trustworthiness and approachability of individuals based on their facial expressions; in assessing the arousal level of conspecifics on the basis of facial expression; in responding to the threat content of words;

in recognizing the function of intonation in sentences; and in identifying voices and the emotional quality of nonverbal sounds. Similarly, I have detailed how the orbitofrontal cortex is involved in tracking reward contingencies to determine whether a particular behavior is advantageous or detrimental; in recognizing and implementing rules for appropriate social behavior; and in keeping goals in mind.

These amygdala and orbitofrontal functions are intensely social. They are, therefore, crucially important in choosing what to say, how to say it, when to say it, and to whom to say it. In addition, such functions are essential for determining the intentions, desires, and emotions of one s interlocutors. Patients with amygdala or orbitofrontal damage are generally diagnosed as having normal language. Schumann (1999) suggests that such patients may actually have normal *grammar*, but impaired language-use *pragmatics*. In general, the pragmatic competence of such patients has not yet been studied.

While other parts of the brain are also involved in interpreting and emitting social signals,[3] the amygdala and the orbitofrontal cortex (in conjunction with the autonomic, endocrine, and musculoskeletal systems) seem to operate, at the most basic level, as an appraisal mechanism for determining the emotional, motivational, and incentive relevance of stimuli including social stimuli, and, therefore, language. Thus, in its role as an evaluator of social signals, this neural appraisal system appears to be a reasonable candidate for the neural mechanism that subserves decision-making in language pragmatics.

Conclusion

This chapter has attempted to show how stimulus appraisal, foraging, and social cognition are implemented largely by the same neural system. Extending this view, I have argued that motivation in second language acquisition, cognitive/motor exploratory activity in learning (with specific reference to second language learning), and decision-making in language pragmatics may actually result from the same brain mechanisms. This perspective provides some consilience in applied linguistics by demonstrating an essential unity at the biological level for three areas that seem quite different at the psychological level.

In addition, this biological perspective allows us to talk about actual material components of the system (amygdala, orbitofrontal cortex, striatum, dopamine, etc.), providing a specificity that can contribute to our understanding of the biology underlying psychological constructs. Although such specificity requires the introduction of substantial neurobiological terminology, it has the advantage of allowing the model to be adjusted as new information is discovered about the functions of the neural substrate. Thus, because of the enormous amount of neurobiological research being produced, refinements in the model will be possible on a regular basis. In addition, such specificity will facilitate the actual testing of the model as new developments in non-invasive neuroimaging technology become available. Therefore, I believe that the continued integration of psychology and neurobiology will contribute significantly to our knowledge of issues important to the field of applied linguistics.

Notes

1. In the Stroop test, subjects are presented with a list of color names (*blue, red, green,* etc.) that are printed in non-corresponding colors (the word *blue*, for example, might be printed in red ink, and vice-versa). The test measures the ability of subjects to identify the color of the print while repressing the tendency to read the color name instead.

2. This link is implicitly recognized by Damasio (1994) in his observation that reasoning involves choosing a nonverbal action, a word, a sentence or some combination thereof, among the many possible at the moment, in connection with a given situation (p. 165).

3. Adolphs (1999) reports that areas in the right somatosensory cortex (including regions known as SI, SII, and insula) are particularly important in recognizing blends of emotions in conspecifics faces. Brothers (1997) reports that in primates, neurons in the superior temporal sulcus are responsive to faces including conspecifics eye movements, head, and gaze direction. She also points out that neurons in the inferior temporal cortex respond to faces and become active when a monkey observes a conspecific walking. The superior temporal sulcus and the inferotemporal cortex have reciprocal connections with the amygdala (Amaral, Price, & Pitkanen, 1992). For discussion, see Schumann (1999).

ANNOTATED BIBLIOGRAPHY

Adolphs, R. (1999). Social cognition and the human brain. *Trends in Cognitive Sciences, 12*, 469 479.

Adolphs describes how the amygdala, orbitofrontal cortex, somatosensory areas, and the peripheral nervous system underpin social cognition, the ability to reason about social and personal issues, and to make hypotheses about the dispositions and intentions of others.

Damasio, A. R. (1994). *Descartes' error: Emotion, reason, and the human brain*. New York: G. P. Putnam's Sons.

This is a very important book. It has proven valuable to both neuroscientists and laymen in understanding the emotional underpinnings of rational cognition. In addition, it provides very clear anatomical and functional accounts of the orbitofrontal cortex, the amygdala, and the peripheral nervous system.

Ikemoto, S., & Panksepp, J. (1999). The role of the nucleus accumbens dopamine in motivated behavior: A unified interpretation with special reference to reward-seeking. *Brain Research Reviews, 31*, 6–41.

The article describes how dopamine innervation of the nucleus accumbens allows organisms to recognize and remember the incentive salience of stimuli. This ability permits animals and humans to undertake behaviors, both motor and cognitive, to achieve their goals.

Scherer, K. R. (1999). Appraisal theory. In T. Dalgleish. & M. J. Power (Eds.), *Handbook of cognition and emotion* (pp. 637–663). New York: John Wiley & Sons.

This article provides an overview of appraisal psychology. It includes a historical perspective, a survey of appraisal theories, and a review of the empirical evidence generated by research on stimulus appraisal.

Schumann, J. H. (1997). *The neurobiology of affect in language.* Boston: Blackwell. (Also published by *Language Learning* as a supplement to volume 48, 1997).

This book proposes a neurobiological mechanism for stimulus appraisal and then shows how it might operate in second language acquisition, primary language acquisition, language use, and cognition in general.

Schumann, J. H. (1999). A neurobiological basis for decision making in language pragmatics. *Pragmatics & Cognition, 7*, 283–311.
This article argues that Damasio's (1994) proposals for the neurobiology subserving personal and social reasoning may also provide a neurobiology for the types of social and personal decisions that must be made, on a continuing basis, in language pragmatics.

UNANNOTATED BIBLIOGRAPHY

Adolphs, R., Cahill, L., Schul, R., & Babinsky, R. (1997). Impaired declarative memory or emotional material following bilateral amygdala damage in humans. *Learning & Memory, 4*, 291 300.

Adolphs, R., Russell, J. A., & Tranel, D. (1999). A role for the human amygdala in recognizing emotional arousal from unpleasant stimuli. *Nature, 10*, 167 171.

Adolphs, R., & Tranel, D. (1999). Preferences for visual stimuli following amygdala damage. *Journal of Cognitive Neuroscience, 11*, 610 616.

Adolphs, R., Tranel, D., & Damasio, A. R. (1998). The human amygdala in social judgment. *Nature, 393*, 470 474.

Adolphs, R., Tranel, D., Damasio, H., & Damasio, A. R. (1994). Impaired recognition of emotion in facial expressions following bilateral damage to the human amygdala. *Nature, 372*, 669 672.

Amaral, D. G., Price J. L., Pitkänen, A., & Carmichael, S. T. (1992). Anatomical organization of the primate amygdaloid complex. In J. P. Aggleton (Ed.), *The amygdala: Neurobiological aspects of emotions, memory, and mental dysfunction* (pp. 1 66). New York: Wily-Liss.

Anderson, S. W., Bechara, A., Damasio, H., Tranel, D., & Damasio, A. R. (1999). Impairment of social and moral behavior related to early damage in human prefrontal cortex. *Nature Neuroscience, 2*, 1032 1037.

Bechara, A., Damasio, H., & Damasio, A. R. (2000). Emotion, decision making and the orbitofrontal cortex. *Cerebral Cortex, 10*, 295 307.

Berridge, K. C., & Robinson, T. E. (1998). What is the role of dopamine in reward: Hedonic impact, reward learning, or incentive salience? *Brain Research Reviews, 28*, 309 369.

Bradley, M. M., Greenwald, M. K., Pety, M. C., & Lang, P. J. (1992). Remembering pictures: Pleasure and arousal in memory. *Journal of Experimental Psycholog:, Learning, Memory and Cognition, 18*, 379 390.

Brothers, L. (1990). The social brain: A project for integrating primate behavior and neurophysiology in a new domain. *Concepts in Neuroscience, 1*, 27 51.

Brothers, L. (1997). *Friday s footprint: How society shapes the human mind*. New York: Oxford University Press.

Cahill, L., Haier, R., Fallon, J., Alkire, M., Tang, C., Keator, D., Wu, J., & McGaugh, J. L. (1996). Amygdala activity at encoding correlated with long-term, free recall of emotional information. *Proceedings of the National Academy of Science USA, 93*, 8016 8012.

Denburg, N. L., Bechara, A., Tranel, D., Hindes, A. R., & Damasio, A. R. (1999). Neuropsychological evidence for why the ability to decide advantageously weakens with advancing age. *Society for Neuroscience Abstracts, 25*, 32.

Depue, R. A., & Collins, P. F. (1999). Neurobiology of the structure of personality: Dopamine, facilitation of incentive motivation, and extraversion. *Behavioral and Brain Sciences, 22*, 491 569.

Deutch, A. Y., Bourdelais, A. J., & Zahm, D. S. (1993). The nucleus accumbens core and shell: Accumbal compartments and their functional attributes. In P.W. Kalivas, & C. D. Barnes (Eds.), *Limbic motor circuits and neuropsychiatry* (pp. 45 88). Boca Raton: CRC Press.

Frijda, N. H. (1987). Emotion, cognitive structure and action tendency. *Cognition & Emotion, 1*, 115 143.

Frijda, N. H., Kuipers, P., & ter Schure, E. (1989). Relations among emotion, appraisal, and emotional action readiness. *Journal of Personality and Social Psychology, 57*, 212 228.

Gardner, R. C. (1985). *Social psychology and second language learning: The role of attitudes and motivation.* London: Edward Arnold.

Hamann, S. B., Ely, T. D., Grafton, S. T., & Kilts, C. D. (1999). Amygdala activity related to enhanced memory for pleasant and aversive stimuli. *Nature Neuroscience, 2*, 289 293.

Heberlein, H. S., Adolphs, R., Tranel, D., Kemmerer, D., Anderson, S., & Damasio, A. R. (1998). Impaired attribution of social meanings to abstract dynamic visual patterns following damage to the amygdala. *Society for Neuroscience Abstracts, 24*, 1176.

Heimer, L., Alheid, G. F., & Zahm, D. S. (1993). The basal forebrain organization: An anatomical framework for motor aspects of drive and motivation. In P.W. Kalivas & C. D. Barnes (Eds.), *Limbic motor circuits and neuropsychiatry* (pp. 1 43). Boca Raton: CRC Press.

Isenberg, N., Silbersweig, D., Engelien, A., Emmerich, S., Malavade, K., Beattie, B., Leon, A. C., & Stein, E. (1999). Linguistic threat activates the human amygdala. *Proceedings of the National Academy of Science USA, 96*, 10456 10459.

Kalivas, P. W., Churchill, L., & Klitenick, M. A. (1993). The circuitry mediating the translation of motivational stimuli into adaptive motor responses. In P. W. Kalivas & C. D. Barnes (Eds.), *Limbic motor circuits and neuropsychiatry* (pp. 237 287). Boca Raton: CRC Press.

Klüver, H., & Bucy, P. C. (1939). Preliminary analysis of functions of the temporal lobes in monkeys. *Archives of Neurology and Psychiatry, 42*, 979 1000.

LeDoux, J. (1996). *The emotional brain*. New York: Simon & Schuster.

Leventhal, H., & Scherer, K. R. (1987). The relationship of emotion to cognition: A functional approach to a semantic controversy. *Cognition & Emotion, 1*, 3 28.

McGaugh, J. L., Roozendaal, B., & Cahill, L. (2000). Modulation of memory storage by stress hormones and the amygdaloid complex. In M. S. Gazzaniga (Ed.), *The new cognitive neurosciences* (pp. 1081 1098). Cambridge, MA: MIT Press.

Mealey, L., Daood, C., & Krage, M. (1996). Enhanced memory for faces of cheaters. *Ethology and Sociobiology, 17*, 119 128.

Mogenson, G. J., Brudzynski, S. M., Wu, M., Yang, C. R., & Yim, C. C. Y. (1993). From motivation to action: A review of dopaminergic regulation of limbic nucleus accumbens ventral pallidum pedunculopontine nucleus circuitries involved in limbic-motor integration. In P.W. Kalivas & C.D. Barnes (Eds.), *Limbic motor circuits and neuropsychiatry* (pp. 193 236). Boca Raton: CRC Press.

Montague, P. R., Dayan, P., Pearson, C., & Sejnowski, T. J. (1995). Bee foraging in uncertain environments using predictive Hebbian learning. *Nature*, *337*, 725 728.

Ortony, A., Clore, G. L., & Collins, A. (1998). *The cognitive structure of emotions*. New York: Cambridge University Press.

Robbins, T. W., & Everitt, B. J. (1996). Neurobehavioral mechanisms of reward and motivation. *Current Opinion in Neurobiology, 6*, 228 236.

Rolls, E. T. (1999). *The brain and emotion*. Oxford: Oxford University Press.

Rolls, E. T. (2000). The orbitofrontal cortex and reward. *Cerebral Cortex, 10*, 284 294.

Rolls, E. T. (1995). A theory of emotion and consciousness, and its application to understanding the neural basis of emotion. In M.S. Gazzaniga (Ed.), *The cognitive neurosciences* (pp.1091 1106). Cambridge, MA: MIT Press.

Scherer, K. R. (1999). Appraisal theory. In T. Dalgleish & M. J. Power (Eds.), *Handbook of cognition and emotion* (pp. 637 663). New York: John Wiley & Sons.

Scherer, K. R. (1988). Criteria for emotion-antecedent appraisal: A review. In V. Hamilton, G. H. Bower, & N. H. Frijda (Eds.). *Cognitive perspectives on emotion and motivation* (pp.89 126). Dordrecht, The Netherlands: Kluwer.

Scherer, K.R. (1984). Emotion as a multicomponent process: A model and some cross-culture data. In P. Shaver (Ed.) *Review of personality and social psychology*, Vol. 5, *Emotions, relationships and health* (pp. 37 63). Beverly Hills, CA: Sage.

Schultz, W., Tremblay, L., & Hollerman, J. R. (2000). Reward processing in primate orbitofrontal cortex and basal ganglia. *Cerebral Cortex, 10*, 272 283.

Schumann, J. H. (2001). Learning as foraging. In Z. Dörnyei & R. Schmidt (Eds.), *Motivation and second language acquisition* (pp. 21–28). Honolulu, HI: The University of Hawaii, Second Language Teaching and Curriculum Center.

Schumann, J. H. (in press). Biology, biography and bilingualism: A neurobiological perspective on variable success in second language acquisition. In R. Franceschini (Ed.), *Sprachbiographien linguistic biographies: Leben mit meheren Sprachen*. Tübingen: Stauffenberg Verlag.

Scott, S. K., Young, A. W., Calder, A. J., Hellawell, D. J., Aggleton, J. P., & Johnson, M. (1997). Impaired auditory recognition of fear and anger following bilateral amygdala lesions. *Nature, 385*, 254–257.

Skinner, R. D., & Garcia-Rill, E. (1993). Mesolimbic interactions with mesopontine modulation of locomotion. In P.W. Kalivas & C. D. Barnes (Eds.), *Limbic motor circuits and neuropsychiatry* (pp. 155–191). Boca Raton: CRC Press.

Young, A. W., Aggleton, J. P., Hellawell, D. J., Johnson, M., Broks, P., & Hanley, J. R. (1995). Face processing impairments after amygdalectomy. *Brain, 118*, 15–24.