

DRAFT 9/6/05

## The interactional instinct: The evolution and acquisition of language

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Paper presented at the Congress of the International Association for applied Linguistics,  
Madison, Wisconsin, August, 24-29, 2005.

In this presentation, we outline a perspective on language acquisition based on evolutionary biology and neurobiology. We argue that language is a cultural artifact that emerges as a complex adaptive system from the verbal interaction among humans. We see the ubiquity of language acquisition among children generation after generation as the product of an interactional instinct that, as Tomasello indicates, is based on an innate drive to communicate with and become like conspecifics.

Language as a cultural artifact.

Lee and Schumann (2003) (following on work by Batali, 1998; Kirby, 1998; Steels, 1998; DeBoer, 2002; MacNeilage & Davis, 2000; Deacon, 1997) present a perspective on language evolution in which a group of hominids have acquired the ability to make particulate sounds and to use them to form words, eventually producing a substantial lexicon. We suggest that further developments in the structure of this oral language emerge through the conversational interaction among the hominids as they attempt to express meanings with consistent forms over time. This position follows from the principles of complexity theory in which complex adaptive systems are seen to spontaneously emerge from the interaction of a large number of agents and/or large number of items. Such structure is seen in the large-scale flight formation of flocks of birds where each individual bird interacts on the basis of certain principles with its local neighbors. Traffic jams have also been explained in terms of complex adaptive systems where the accrual of a sufficiently large number of automobiles requires that the drivers not merely focus on their goal but also on the interaction with the cars immediately in front of them, behind them and on their sides. This interaction then results in the cars moving as a single unit until their numbers fall or until the distance between them reduces the need for local interaction. Ant colonies are also characterized as complex adaptive systems in which individual ants behave according to local rules without any awareness of the total state of the colony. These local interactions ultimately produce elaborate anthills with intricate structure. Slime molds are amoebae that operate in the environment as individuals, but when supplies of

nutrients become depleted the cells spontaneously organize into large configurations which move across the forest floor as single structures. When sources of food again become plentiful, the amoebae individuate and operate on their own ( Briggs & Peat,1989; Holland,1995; Johnson, 2001; Larsen-Freeman,1997; Prigogine,1998; Weber & Deacon, 2002).

From our perspective (Lee & Schumann, 2003), linguistic structure emerges as a complex adaptive system from the verbal interaction of hominids attempting to communicate with each other. Individuals organize lexical items into structures, and if the structures are efficiently producible, comprehensible and learnable, then their use will spread throughout the community and become part of the "grammar" of the language. What the conversational interaction does is to insure that the forms that ultimately become part of the grammar are those that fit the cognitive and motor capacities of the brain (Kirby, 1998). The vetting process inherent in the interaction modifies the grammatical structures to fit the brain rather than requiring the brain to evolve a genetically based mechanism designed to specify the form of the language. The resulting language is a technology that is passed on to succeeding generations as a cultural artifact.

But in order for this technological inheritance to take place some genetic assimilation may be required. However, we see such selection taking place not on the principles of universal grammar, but rather on more abstract processes. In other words, we would see genetic assimilation producing capacities for joint attention, for understanding communicative

intentions, and for cultural learning (Tomasello, 1999, 2003). Children would be born with the innate capacity to identify with conspecifics, to imitate both the result and intentions of conspecifics' actions, and with a powerful drive to pay attention to faces, voices and body movements of conspecifics. Children have the aptitude for language acquisition because interaction has molded the language to fit their learning capacities. What is innate is the child's appetite for language learning.

Language is dependent on the earlier evolution pattern-finding capacities.

Tomasello (2003) points out that another crucial prerequisite for language acquisition is the ability of children to detect patterns in their environment. He reports research that has demonstrated that infants can detect artificial nonsense words made up of three syllable sequences. Later the infants respond to those words, but they do not respond to the syllables presented in a different order (Saffran, Aslin, & Newport, 1996). Marcus, Vijayan, Bandi Rao, & Vishton (1999) briefly trained seven month olds on three syllable sequences of the form ABB. Later the infants responded to this pattern even when the syllables were different (e.g. XYY). Tomasello notes that this ability to detect abstract patterns in auditory and visual input is not unique to humans. Other primates such as tamarin monkeys also have this skill. Therefore, pattern finding is a cognitive capacity that has a deep evolutionary history and certainly cannot be seen as a specific adaptation for language.

The innate "interactional instinct."

We have argued that language is a culturally transmitted artifact or technology that requires no innate a priori linguistic representations. We have also argued that a major mechanism in language acquisition is a domain general system for tracking input frequencies and for discovering patterns in the input. What we consider crucial for language acquisition is what we will call an "interactional Instinct." This instinct is an innate drive among human infants to interact with conspecific caregivers. While such an instinct may exist in other social animals, we contend that in humans it has become much more powerful.

The human brain may be seen as composed of three major functions: posterior sensory systems (touch, hearing, vision), anterior motor systems, and a more or less ventral and mesial appraisal system. The appraisal mechanism determines the emotional relevance and motivational significance of stimuli received by the sensory systems, and it directs appropriate action by motor systems vis-à-vis those stimuli. The appraisal system determines three kinds of value: homeostatic, sociostatic, and somatic. Homeostatic value is centered on the autonomic nervous system and involves heart rate, body temperature, hunger, thirst, sexual drives etc. An organism strives for homeostasis and undertakes motor activity in the world in order to maintain appropriate balance among these bodily states. Sociostatic value is essentially what underlies the interactional instinct. It motivates the organism to take action to achieve attachment and social affiliation with conspecifics who are initially caregivers and who later comprise members of the community at large.

Somatic value involves the preferences and aversions that we acquire in our lifetime. They are not innate, but instead are the product of our experience with stimuli we encounter in the world.

Evidence for sociostatic value and an interactional instinct comes from observations of human neonate behavior. Infants from shortly after birth seek out the face and voice of their mothers. They can distinguish happy, sad, and surprised facial expressions within an hours of birth. Very early they vocalize to get caregivers' attention and they coordinate their vocalizations with caregiver speech in a manner similar to conversational turn taking (Schumann 1997). Schore (1994) presents arguments that this interaction actually builds a postnatal brain by stimulating axonal extension from the brainstem to the pre-frontal cortex . It would appear that the interactional instinct exists because human infants are born prematurely with the result that substantial brain development takes place postnatally. The emotional entrainment of the child on caregiver-conspecifics maybe evolutionarily designed to provide appropriate brain development and hence socialization during the extended human infant and juvenile periods.

Greenberg and Shanker (2004) offer a perspective that sees all of child language development as proceeding on an emotional base. In the evolution of language they argue that a crucial step was the acquisition of the ability to separate the perception of something from action that might be taken toward that thing. This is accomplished by forming an image of the perceived object and imbuing that object with emotional relevance. The

freestanding image then becomes an object of contemplation and focus independent of any action that might be taken towards it. Greenberg and Shanker suggest that same process is recapitulated in child development and leads to the ability to form symbols. In language acquisition such symbols emerge from what the authors call "reciprocal co-regulated emotional interactions" (page 30) between child and adult. In these coregulated interactions, the child signals his intent to the caregiver (to reach for something, to hit someone), and the caregiver responds to that intention. The intent becomes a symbol that child expresses in an emotionally-based interaction, and the caregiver responds to the intention without the child having to take immediate and direct action on that goal or desire (page 31).

The question is most relevant for our research concerns the neurobiology that might serve as an emotional basis for the interactional instinct and ultimately language. Research by Depue & Moronne-Strupinsky (2005) has generated a model for the neurobiology of social affiliation. It is divided into two parts: an appetitive component and a consummatory phase. Luciana (2001) suggests that the biology underlying consummation develops first and involves the expression of endogenous opiates during child-caregiver interaction. These opiates provide the child and the adult with feelings of calmness, attachment, and affiliation with each other. The opiates are modulated by neuropeptides such as vasopressin and oxytocin. They are secreted from the arcuate nucleus in the hypothalamus and project to the central nucleus of the extended amygdala and the bed nucleus of the stria terminalis where they encode general, non-explicit features of the context in which

attachment/affiliation takes place. They also project to the lateral nuclei of the basolateral amygdala and encode the discrete, explicit stimuli related to the affiliative interaction. As children first develop attachment relations with the persons and environmental settings, endogenous opiates which are similar to morphine and heroin induce reward in the form of comfort and pleasantness. The process, we would argue, entrains the child's attentional mechanisms on the caregivers and serves as a hardwired motivational mechanism that insures socialization in general and language acquisition in particular.

These intensely rewarding aspects of the attachment bond become part of the child's sociostatic memory and serve as a template for subsequent affiliative relationships. As the infant grows and becomes capable of self generated action in the world (for example moving, walking), the appetitive aspects of affiliative process develop. Now the child will seek other conspecifics with whom attachments can be made. The neurobiology supporting this appetitive phase involves the ventral tegmental dopamine interactions with the nucleus accumbens shell, the hippocampus, the medial orbital area (13), and as mentioned earlier, the extended amygdala and the basolateral amygdala. The last two regions provide incentive information concerning non-explicit and explicit context reinforcement to the nucleus accumbens shell where it is associated with contextual information (spatial, temporal) from the hippocampus and with appraisal information from the medial orbital cortex.

This neural mechanism corresponds to the mechanism described in Schumann et al (2004) that subserves foraging and learning. The child in encountering conspecifics more distal than immediate caregivers responds to affiliative stimuli such as friendly vocalizations, gestures, smiles, and touch with positive appraisals and a desire to approach. The appraisals are communicated by the medial orbital cortex with contextual information related to the affiliative stimuli coming from the hippocampus and the basolateral and extended amygdala (Depue, et al, in press). Dopaminergic innervation of the nucleus accumbens facilitates the integration of these various inputs and provides a "go" signal for motoric and cognitive approach and exploration of the affiliative target and its context. This transformation of motivational information into motor activity involves projections from the nucleus accumbens shell to the ventromedial ventral pallidum, to the medial dorsal thalamus, to area 32 of the prefrontal cortex, and from there back to the nucleus accumbens core, the ventrolateral ventral pallidum, and then on to pedunculopontine nucleus, the brainstem motor nuclei and finally the spinal cord. The dopamine in this system operates to encode stimuli that are predictive of reward (Shultz, 1997) which in this case would be affiliative interaction with the conspecific. The dopamine provides reward corresponding to that which is generated by the exogenous ingestion of drugs such as nicotine, caffeine, cocaine, amphetamines, and alcohol.

The maturation effects of this mechanism

What we are arguing here is that it is interactional instinct and pattern matching

ability, but not a UG, that subserve human language learning ability. This position also explains observations on this phenomenon abound, neurobiological explanations have been scanty. We believe that it is absolutely necessary to explain this phenomenon from the point of neurobiology because it is the brain that learns language after all.

We argue here that children are advantaged at language learning because their brain is more suitable for this task due at least to the following four aspects.

#### 1. dendritic arborization, synaptogenesis, and pruning

As Figure 1 shows, during infancy and early childhood, the cerebral cortex overproduces synapses (quadrillion synapses) about twice as it will eventually need. Among these, only highly active synapses are selected and survive and less active synapses regress by a process called pruning (use it or lose it) (Huttenlocher, 1979). This process explains why our mental processes became less flexible and creative as we mature. The existence of an exuberant number of synapses in the brain during early childhood may mean that the young brain can encode new information more easily. Synapses are there just waiting for new pieces of information or skills to be encoded. On the other hand, as pruning continues, the brain may lose the ability to encode information and skill as easily as before.

#### 2. Competition between declarative learning system and procedural learning system

There exists a dissociation between declarative memory and procedural memory (Milner, 1959). The former is subserved by cortico-hippocampal system and the other by cortico-basal ganglionic system. Declarative memories are easy to formulate and lose too, but procedural memories are hard to form and robust once they are formed (Aglioti, 1999). Regarding language learning, the former is more relevant to vocabulary learning and the latter to grammar and phonology learning (Schumann et al, 2004; Ulman, 2001).

The two systems develop on a different time schedule on ontogeny. Behavioral studies and studies from neurobiology have proved this point. Procedural learning ability exists even at birth (Harlow, 1959), and fully matures at three month of age in monkeys (Bachevalier and Mishkin, 1984). This is because the cortico-basal ganglionic system matures early. For example, it reaches maturity at the first year of life in humans (Bachevalier, 2001). However, declarative memory formation reaches adult level only at five years of age in humans (Bachevalier and Mishkin, 1984). This is because the maturation of the cortico-hippocampal system proceeds slowly and well into the adulthood (Tanapat et al., 2001). Seress showed that synaptogenesis in the hippocampal formation increases, and a remodeling of the synaptic contacts continues, until the end of the first year in monkeys (1995) and the fifth year in humans (2001). Nadel and Zola-Morgan (1984) attributed infantile amnesia to the late development of declarative system.

There exists an interfering or competitive interaction between the two systems, as Figure 2 shows. Devan et al. (1999) showed that bilateral lesions of the basal ganglia produced a preference for a declarative learning. In addition, Poldrack et al. (2001; 2003) showed in their rat experiments that pre-training lesions of the hippocampal system

facilitate procedural learning and lesions of the basal ganglia facilitate acquisition of declarative learning.

Synthesizing the diverse factors described above, we can extrapolate that children have an advantage over adults in learning grammar and phonology because their cortico-basal ganglionic system may be more effective than that of adults. This hyper-efficiency, in turn, may stem from the fact that the cortico-basal ganglionic system does not have competition and interference from the cortico-hippocampal system in early childhood. This point may also explain why adults language learners have less difficulty in vocabulary learning than in grammar and phonology learning.

### 3. Decline of Dopamine level

DA is critically involved in motivation for learning (Schumann, 1997) in general and for the appetitive phase, in particular (Depue et al, in press) as John has just presented. As Figure 3 shows, DA originates from the ventral tegmental area and substantia nigra pars compacta and projects to the dorsal striatum, nucleus accumbens, and PFC. DA level goes through ontogenetic change like other brain systems. Generally speaking, it increases until the onset of puberty and then tapers down throughout the life. It has been discovered that in rats, dopamine receptors in the striatum are dramatically overproduced, peak at approximately 40 days of age (onset of puberty), and subsequent decline by 58-75% by 120 days (Gelbard et al. 1989; Teicher et al. 1995). The same trend was also found in DA in the PFC (Andersen et al., 2000). The same system of overproduction and pruning has also been

observed in humans. As Figure 4 shows, in childhood, the densities of DA receptors in the striatum rise and fall. After age 20 years, D1 receptors disappear at 3.2% per decade while D2 receptors disappear at about 2.2% per decade (Seeman et al., 1987).

High synaptic density facilitates formation of new associations (Teicher et al., 1995). The high density of DA receptors in the striatum and the PFC until puberty may be another reason that pre-puberty people learn language better than their older counterparts.

#### 4. Decline of Opiate level

As the last part of my presentation, I will discuss how opiate and other neuropeptides levels change ontogenetically.

As John explained,  $\mu$ -opiate ( $\mu$ O) is critically involved in the process of interaction, especially at the phase of consummation.  $\mu$ -opiate receptor expression and density also undergo developmental change.  $\mu$ OR densities are high in the early postnatal period when the infant spends most time with its caretaker (Pintar & Scott 1993). The change of opiate level is so dramatic that in the brain of a human neonate it is 100 times greater than in the brain at older ages (Waterhouse, L., Fein, D., & Modahl, C., 1996). This type of ontogenetic change also occurs to the level of neuropeptides that modulate opiates, which are oxytocin and later vasopressin, as explained in John's presentation. Both are also overproduced and pruned later (Insel & Winslow, 1998). The superabundance of the neurochemicals in the child brain must drive it to an intense interaction with conspecifics, and may be another factor that explains why children have an advantage over adults in

language learning.

## 5. Conclusion

In conclusion, we believe that there is a neurobiology that subserves an emotional basis for language acquisition. This biological substrate guarantees successful language acquisition in all normal children, and developmental changes in the system may constitute to difficulties older learners experience in SLA.

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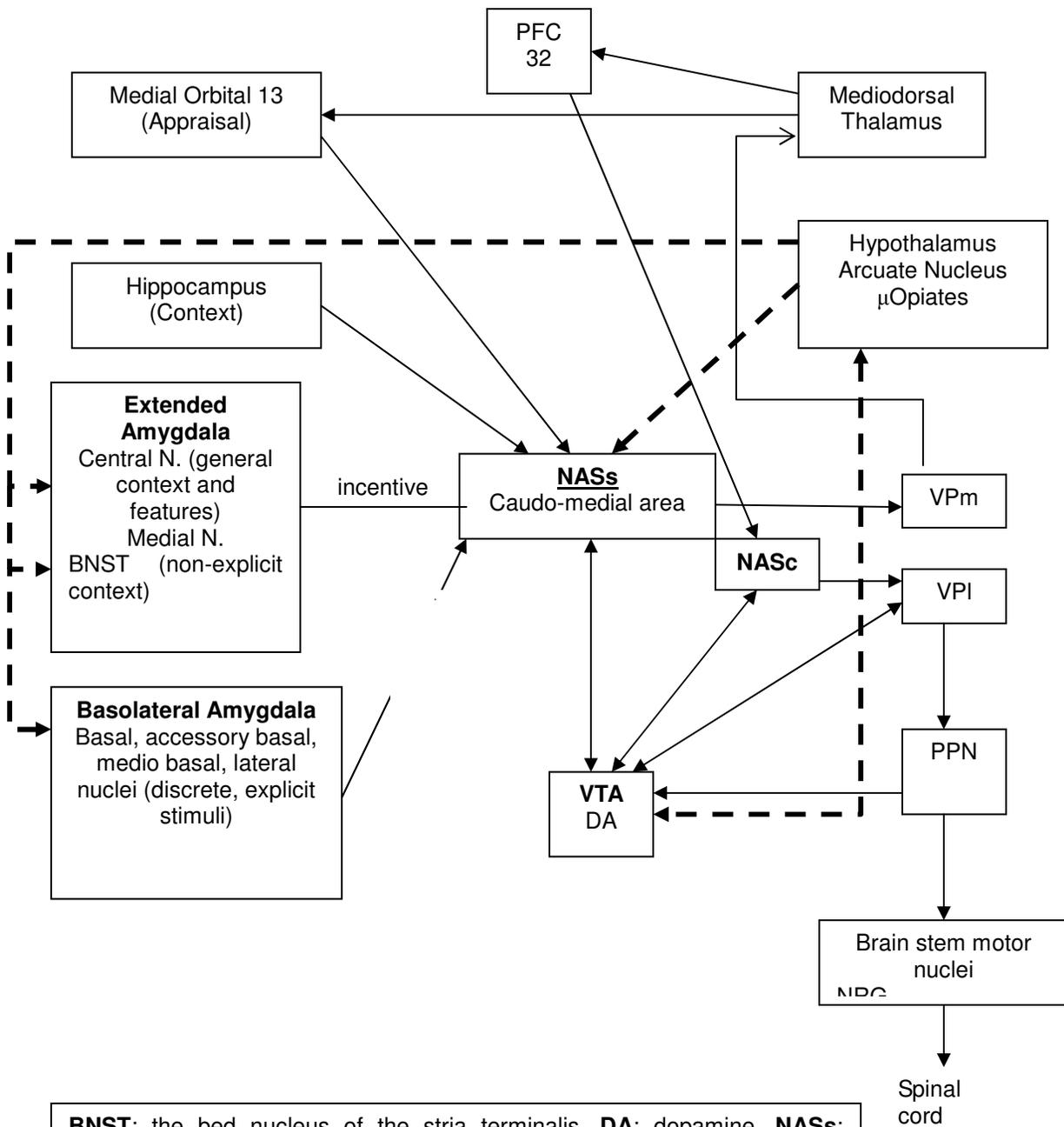
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Figure 1: Neurobiology of Interactional Instinct



**BNST:** the bed nucleus of the stria terminalis, **DA:** dopamine, **NASSs:** nucleus accumbens shell, **NASSc:** nucleus accumbens core, **PFC:** prefrontal cortex, **PPN:** pedunculopontine nucleus, **VPM:** ventromedial ventral pallidum, **VPI:** dorsolateral ventral pallidum **VTA:** ventral tegmental area,

Figure 2 (Taken From Huttenlocher, 1979): Ontogenetic change of synaptic density

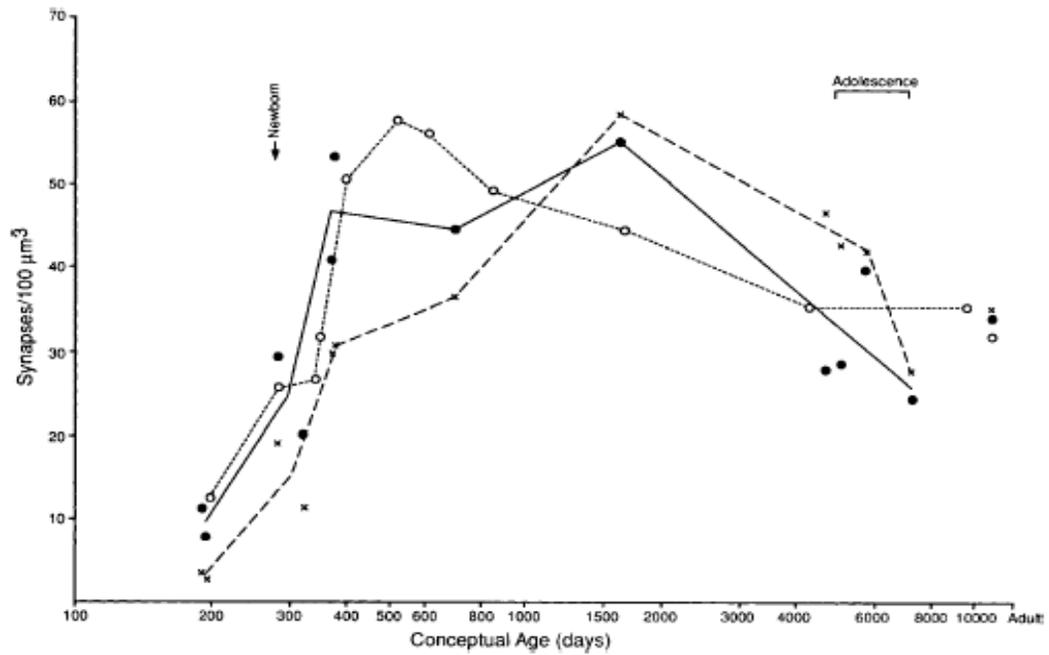


Fig. 2. Mean synaptic density in synapses/100 μm³ in auditory, calcarine, and prefrontal cortex at various ages. Open circles, visual cortex (area 17); filled circles, auditory cortex; x, prefrontal cortex (middle frontal gyrus).

Figure 3: Competition between declarative memory and procedural memory

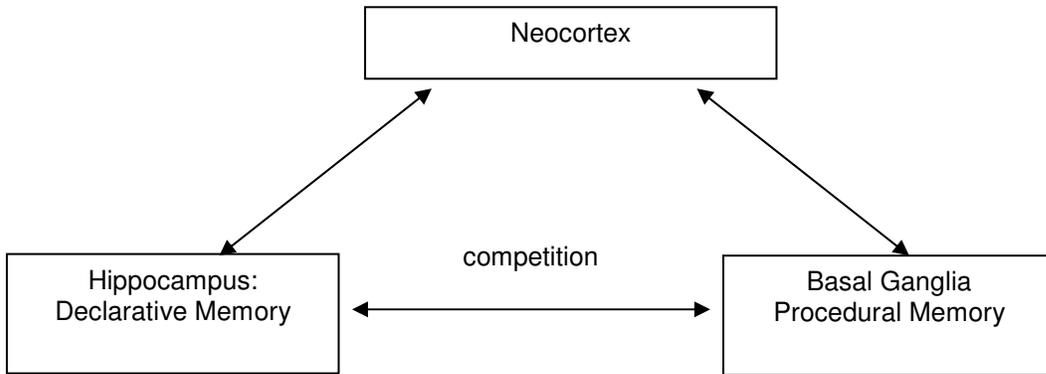


Figure 4: DA Pathways

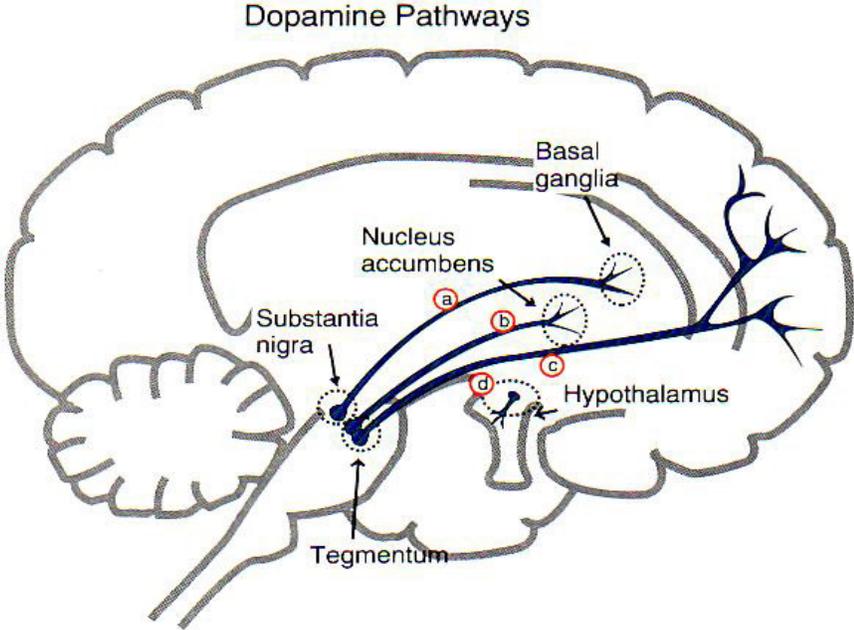


Figure 5 (Taken from Seeman et al., 1987): Ontogenetic change of DA levels

