Journal of Behavioral and Brain Science, 2017, 7, 674-704
http://www.scirp.org/journal/jbbs
ISSN Online: 2160-5874
ISSN Print: 2160-5866

The Separate Development of Children's Listener and Speaker Behavior and the Intercept as Behavioral Metamorphosis

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How to cite this paper: Greer, R.D., Pohl, P., Du, L. and Moschella, J.L. (2017) The Separate Development of Children's Listener and Speaker Behavior and the Intercept as Behavioral Metamorphosis. *Journal of Behavioral and Brain Science*, **7**, 674-704.
https://doi.org/10.4236/jbbs.2017.713045

Received: October 30, 2017
Accepted: December 11, 2017
Published: December 14, 2017

Abstract

The study of verbal behavior focuses on communicative functions of the speakers/producers as they affect the behavior of listeners/observers. Effects on the listener reinforce the speaker and the listener/observer benefits (*i.e.*, is reinforced) from the behavior of the speaker/producer. The interlocking of, and exchange of, the speaker and listener behavior between individuals and within one's own skin constitute bidirectional operants. These bidirectional operants are instances of social interactions and measures of social behavior. Evidence suggests that the act of listening, among other observing responses, is initially developmentally independent from speaker behavior. How they become joined parallels the biological phenomenon of metamorphosis. The succession of changes has been empirically identified as a succession of verbal behavior development cusps, which are described in their sequence biologically as a manifestation of functional metamorphosis. The onset of a cusp constitutes first instances of behavior and accompanying stimulus control that allows infants and children to contact parts of the environment for the first time resulting in their learning things impossible to learn before or learning faster. Cusps for the intercept of the speaker and listener lead to bidirectional operants and provide explanations for how children incidentally learn the names of things, become increasingly social, and make subsequent complex behavior possible. Many of the cusps identified in our research resulted from the missing behavior and stimulus control of children with autism. Once cusps were established, these children learned things they could not learn before, learned faster, and learned by contacting parts of the social environment they could not contact before. These findings led to a theory of verbal behavior development that point to the selection of bidirectional operants as behavioral phenotypes during functional metamorphosis, which has enhanced the survival of *Homo sapiens* through emergent symbolic skills for more effective collaboration between two or more individuals.

Keywords

Bidirectional Operant, Verbal Behavior Development, Comprehensive Behavior Analysis Systems Approach to Education, Behavioral Development

1. Introduction

When verbal behavioral developmental repertoires and the pre-verbal foundational repertoires are demonstrated for the first time they are described as verbal behavior developmental cusps (e.g., first incidences of mands or requests, tacts or declaratives, or the incidental learning of the names of things or bidirectional naming (BiN). The cusps that are present, or not present, in children's repertoires determine the degree to which children: 1) communicate, 2) contact social contingencies, 3) learn from incidental experiences, and 4) do, or do not, learn from different types of instruction. The behaviors of communicating include: 1) language, or the lexicon (e.g., a dictionary and grammar of a particular language), and 2) the range of behaviors that constitute how individuals affect (*i.e.*, communicate to) and are affected (*i.e.*, communicated with) by each other's behavior. We use this meaning of the term verbal consistent with Skinner's [1] [2] usage, as well as the expansion of the meaning of verbal resulting from decades of research in verbal behavior development and relational stimulus control [3] [4]. Verbal behavior is communicative behavior that embraces the lexicon of language as well as the vocal and non-vocal behaviors of communication.

Verbal behavior develops in children's lifetime as a result of learning new social reinforcers for observing (e.g., listening and looking) and producing responses (e.g., speaking as a result of social stimulus control). These newly learned reinforcers, in turn, lead to the emergence of learned motivating conditions and new antecedent stimulus control, including the frames of relational stimulus control [4] [5]. This new stimulus control was not possible before the onset of certain verbal developmental cusps. VBDT argues that these experiences and the wherewithal to contact them constitute the environmental sources for the kinds of neurological development documented by Kuhl and colleagues [6] [7] [8]. Thus, cusps are part of contextual control involved or make that contextual control possible. For example, the particular function of a word, saying the word fox as a type of mand/request (*i.e.*, "Look out!") or tact/declarative ("Oh yes, I see it"), depends on the context. But what is context? We argue that it is, in part, the particular learned reinforcers for using that word socially. The use, or intended function, depends on a particular reinforcement function and, in turn, the motivating conditions associated with a particular reinforcer. In behavior analysis, each type of reinforcement is accompanied with a motivating condition. For example, swallowing water reinforces drinking and a related motivating conditions might be the consumption of salt. A newly learned reinforcer (*i.e.*, the sound of mother's voice learned as a reinforcer for observing in utero) also results in new motivating conditions (*i.e.*, deprivation of hearing mother's voice enhances reinforcement for observing). Together, the newly learned motivating condition and the newly learned reinforcer make the relevant stimulus discriminatively salient (*i.e.*, stimuli signaling the appearance of mother's voice such as the sound of footsteps). Different contexts consist of different learned social reinforcement or punishment contingencies that act to select the particular discriminative stimulus out of many. A history that leads to multiple learned reinforcers for various behaviors establishes this contextual control as we describe in the tables that follow.

Research findings from other disciplinary approaches to development have demonstrated the importance of ontogeny (*i.e.*, experience) including comparative psychology [9], cognitive developmental psychology [10], and developmental neuroscience [6]. The role of experience has also been identified in behavioral analysis of complex human behavior and is its research focus [4] [11]. Behavioral analyses of verbal behavior development contribute by identifying how children come to contact parts of the environment that then provide the experiential stimuli for their contacting still other experiences. In this context, and with a view towards the far-reaching behavioral changes children regularly show during language development, we began asking ourselves whether it would be productive—both from a theoretical and applied perspective-to view some of these conspicuous transformations in behavioral functionality as exemplars of behavioral metamorphosis.

We remembered that Skinner [12], Catania [13] [14] [15] [16], and Donahoe [17] provided strong arguments for the functional similarities between natural selection in phylogeny and selection by reinforcement during ontogeny, and that Donahoe [18] had reviewed state-of-the-art evolutionary biology from the perspective of current developments in the experimental analysis of behavior. But a comprehensive search of the literature on metamorphosis and behavior only turned up one brief discussion of metamorphosis and adaptation in the behavior of developing mammals [19].

The lack of findings in the biology research literature on metamorphosis eventually led us to Charles Darwin and one of his far-sighted intuitions. Commenting on the birth of Haeckel's child, Darwin noted in a letter to him in 1865, "You will be astonished to find how the whole mental disposition of your child changes with advancing years. A young child, and the same when nearly grown, sometimes differ almost as much as do a caterpillar and butterfly" [20]. The body of research on verbal behavior development represented in what follows underlines Darwin's intuition in that it suggests that differences in children's being able to contact critical parts of their environment before and after the emergence of specific developmental cusps are similar to the effects of structural metamorphosis on organisms but on a *functional* or *behavioral* level.

These findings in verbal behavior development within both basic and applied science are implicitly translational. **Figure 1** displays the verbal behavior

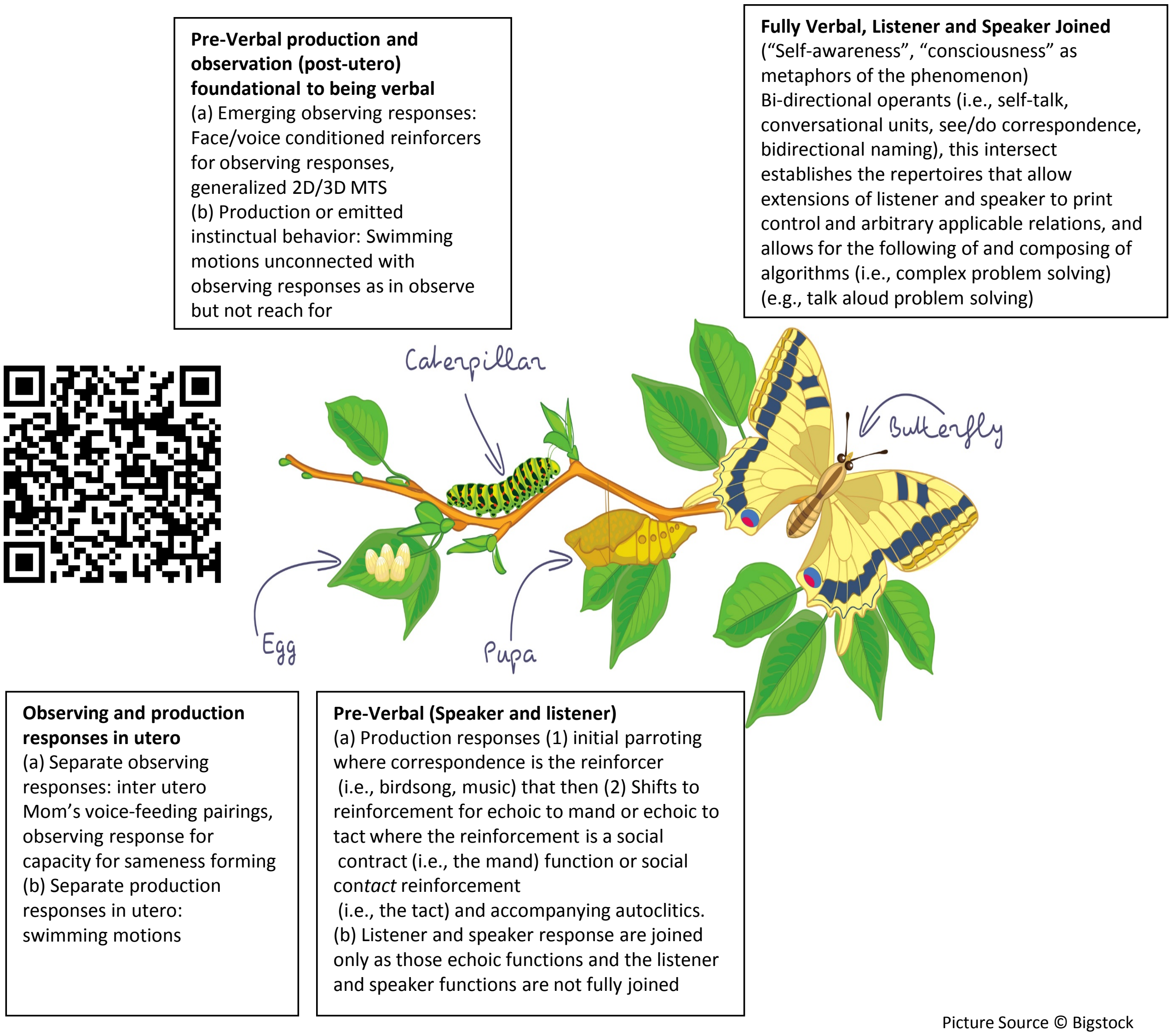

Figure 1. Verbal developmental milestones as behavioral metamorphosis in humans and structural metamorphosis in the life cycle of the butterfly.

development of individuals in parallel to the metamorphosis of a butterfly. Readers can scan the QR code below for a dynamic display of this figure[1].

2. Onset of Verbal Developmental Cusps as Metamorphosis

Education and development are inextricably intertwined. From the behavior analytic perspective, it is experience, not the passage of time alone, that leads to development in an individual [21] [22] [23] [24]. There is a long history of behavior analyses of development that includes pioneers such as Jacob Gerwirtz, Sidney Bijou, Donald Baer, Barbara Etzel, Betty Hartman, and Todd Risley, to name a few [25]. Verbal Behavior Developmental Theory (VBDT) and research

[1]Readers need to download a QR scanner on smartphones or tablets (*i.e.*, QR reader) to view these QR codes.

[3] [26] [27] [28] builds on that history and extends it to behavioral analysis of development and verbal behavior. The analysis focuses on how verbal behavior develops from experience, including how children come to contact experiences, and how that development determines how and what a child can be taught directly or learn incidentally.

Children who lack the presence of cusps and capabilities are first identified by measures of their rate of learning in curricular areas (*i.e.*, instructional trials to mastery, learning from instruction and demonstration. Detailed algorithms test for the presence or absence of a cusp or a cusp that is also a new learning capability (e.g., child demonstrates they learn from vicarious contact with instruction or exposure and no instruction) [26] [27]. Children may lack a cusp, either because they lack environmental experiences that form the cusp (*i.e.*, environmental impoverishment), or as a result of native disabilities. Children's instructional and experiential histories may or may not contain the key experiences that establish verbal developmental (VBD) cusps. Children who are exposed to a rich verbal community are more likely to acquire VBD cusps, and by contrast, children who come from low-language interaction homes may not acquire them [25]. Many children diagnosed with autism are missing one or more cusps. The induction of cusps and capabilities can radically change a child such that they can contact experiences that, in turn, allow the child to learn things they could not before, learn faster, or learn in new ways [24] [29]. Teachers, in turn, need to change the way they teach to match the countless new opportunities to learn that the child can now contact. For example, providing instruction and examples prior to providing response opportunities leads to faster outcomes if a child demonstrates the cusp of bidirectional BiN [30]; however, if a child lacks that cusp, they learn little, if anything, from response-antecedent instruction and must learn mostly from direct consequences [31]. Moreover, certain cusps make it possible for learning multiple responses to the same stimulus from learning one [32], as is the case when transformation of stimulus function across saying and writing is present and the child demonstrates incidental language learning (BiN) [33]. In the latter case, simply hearing a word spoken for an object can result in the child learning the word-object relation (*i.e.*, "meaning" of the word), learning how to spell the word by speaking the letter names, and writing the word, all without direct instruction. In addition, any respondent events (*i.e.*, emotions) occurring as the word is spoken relative to the "referent" may become part of the stimulus control of any of the learning outcomes. **Figure 2** shows how these cusps are related to each stage of verbal development and are thus analogous to the metamorphosis of a butterfly.

Verbal behavior developmental research seeks to identify specific sequences of experiences (the basic science) and developmental interventions (the applied science) that lead to the establishment of these cusps. The current evidence suggests that many of these cusps result from establishing new or learned reinforcers that simultaneously establish new motivational conditions [23] [34] [35] [36]. These protocols provide the key experiences that result in conditioning

Figure 2. Four verbal behavior developmental metamorphosis stages.

new reinforcers and consequently lead to verbal development. Examples include a protocol to condition adults' faces and voices for observing adults, resulting in faster rates of learning [37], and a conditioning protocol to establish print as reinforcement for observing, resulting in generalized visual match to sample [38] [39] [40]. These latter cusps are pre-verbal foundational cusps as shown in **Table 1**, with the research-based protocols to induce them. Pre-verbal foundational cusps typically occur in utero and infancy but are found missing in children with severe developmental delays.

The developmental trajectory involves a history of a child contacting what are initially independent observing (e.g., looking and listening) and producing responses (speaking) [1] [45] that become coordinated or joined as a result of contact with contingencies. An example on the observing side is *the progression from*: 1) observing mom's face after birth as a result of vocal sounds having been conditioned in utero and then paired with the mom's face after birth, to 2) *listening to* phonemes. The production responses of babbling contact relations with the mother's voice and emulation of mom's sounds (*i.e.*, parroting or

Table 1. Verbal behavior developmental milestones: Pre-verbal foundational cusps.

Verbal behavior cusp	A cusp allows a child to learn things that could not be learned before, learn faster, or learn in new ways	
Verbal Milestones: Pre-Verbal Foundational Cusps		
Metamorphosis status: Egg-Caterpillar		
Cusp	Description	Protocol Procedure & Research
Orient to Others' Voices	A verbal behavior cusp that enables one to attend to adults' voices *New Learning Possibilities*: Orients towards speaker-name called and direction given Orients towards speaker-name called and approval given Orients towards speaker entering the room	Voice Conditioning Protocol [41] [42]
Orient to Others' Faces/Presence of Others	A verbal behavior cusp that enables one to attend to adults' faces *New Learning Possibilities*: Looks at speaker's face when greeted with name Looks at speaker's face when given an approval Looks at adult's face when adult comes to eye level within 2 feet Looks at peer's face when peer comes to eye level within 2 feet Use coordinated eye contact with words and/or other strategies to communicate Looks at parent or caregiver when they leave the room Approaches adult and physically guide his/her body part to assist	Face Conditioning Protocol [37]
Generalized Identity Matching	A verbal behavior cusp that enables one to match novel stimuli (generalized match to sample) *New Learning Possibilities*: Visual discrimination learning becomes possible.	2D Conditioning Protocol using stimulus-stimulus pairing [39] [40] 3D Conditioning Protocol [38] [43]
"Capacity for Sameness" Across Senses	A verbal behavior cusp that enables one to match sameness across gustatory, auditory, visual, olfactory, and tactile senses *New Learning Possibilities*: Cross-modal relations become possible	Sensory Matching Protocol using multiple exemplar instruction [44]

canonical babbling). Previously learned reinforcement value for mom's voice leads to the learning of correspondence between mom's and baby's speech as reinforcement that is the source parroting/canonical babbling [46]. Parroting is pre-verbal speech (*i.e.*, not affected by the behavior of another listener) but sets the stage for the child emitting spoken sounds that, in turn, produces a magical result, a verbal effect on another. When the parroted word enters a mand or tact function, this is a major step towards becoming verbal. The speaker responses then expand as the child contacts more echoic to mand or echoic to tact experiences. The development of the functional verbal repertoires such as mands and tacts allows the child to respond to natural establishing operations and recruit social attention from adults and peers more readily. However, until the individual rotates the listener and speaker functions as a dialogue, as in self-talk alternation of listener and speaker, as in fantasy play, the child is not fully verbal.

Table 2 lists the listener and speaker cusps, as they exist independently, before they are joined and the child is fully verbal.

One becomes truly verbal when the speaker and listener are joined such that the child talks to herself. The evidence for this includes research on see and do correspondence [74], self-talk in fantasy play [68], and BiN (bidirectional operants) [52] [75] [76], as listed in Table 3. Once this relation is present, contact with experiences and instruction lead to the benefits of following algorithms as listener/reader and producing algorithms as speaker/writer. From a radical behavioral perspective, this intersection of listener and speaker constitutes verbal thinking [1] [2] [3]. One could even argue this is the onset of consciousness since it would appear that non-verbal consciousness is not viable even as a cognitive psychological construct. We maintain that the intersect of speaker and listener during verbal development is a veritable manifestation of behavioral metamorphosis. The comparative biology behind this contention is discussed together with its theoretical implications in the coda following our further delineation of the empirical milestones of verbal development.

The three cusps that constitute new learning capabilities are: Generalized imitation [77] [83], observational learning [91] [92] [93] [95] [96] [97] and BiN [28] [75] [89]. By capabilities we mean that the child reliably demonstrates ways to learn that they could not do before experience allowed them to do so. The chrysalis forms as the numbers and types of independent speaker and listener responses accrue. With the onset of generalized imitation looking and reproducing what is seen becomes a reinforcer because of the correspondence between seeing and doing. This is likely an extension of what happens when an infant finally can reach for what they are observing after considerable attempts to do so. Observing and producing responses intersect. Once a child imitates, because the correspondence is reinforcement [5] [46], they can be shown what to do and will attempt to duplicate with few or no prompts. Learning from social contact becomes more prevalent. That is, the observing and producing responses become more frequently reinforced by social reinforcement. A more advanced example of this occurs when children come to learn from observing the consequences received by others [98]. The first time the child demonstrates these learning capabilities the sources of reinforcement shifts from reinforcement delivered from instruction to the learned reinforcement of the behavioral effect. At this point, the child does not need to be reinforced by the instructor; rather, the reinforcement is embedded in the new learned reinforcer that is part of the operant. By extension, the new reinforcers then lead to other incidental pairings that, in turn, result in still other learned reinforcers that select out still other behaviors. The shift in the type of reinforcement not only allows one to be more independent, but also results in the hundreds and thousands of new learning opportunities for the individual. The individual has access to the unlimited possibilities. BiN then makes it possible for the print stimuli to join with the auditory stimuli. And that in turn makes all the symbolic relations (*i.e.*, reading,

Table 2. Verbal behavior developmental milestones: Listener and speaker.

Verbal Milestones: Listener		
Metamorphosis status: Caterpillar		
Cusp	Description	Protocol Procedure & Research
Auditory Matching	Generalized auditory MTS for speech. A verbal behavior cusp that enables one to discriminate between positive and negative auditory exemplars by matching the sample sound to the matching exemplar. Must be eliminated as source for faulty echoics.	Auditory Matching Protocol [47] [48] [49]
	New Learning Possibilities: Improves or eliminates faulty echoics and collateral effect may be enhancement of conditioned reinforcement for voices	
Listener Literacy (Phonemic stimulus control, or "phonemic awareness")	A verbal behavior cusp that enables one to learn from spoken instructions with or without the presence of visual distractors	Listener Emersion [42] [50] [51]
	New Learning Possibilities: With the development of basic listener literacy, the child can learn word-object relations as a listener. The child no longer relies only on visual cues but responds to vowel-consonant control for listener responses (verbally governed behavior). Some research suggests that listener literacy is a foundational cusp for reading comprehension [3].	
Verbal Milestones: Speaker		
Metamorphosis status: Caterpillar-Chrysalis		
Parroting	A verbal behavior cusp that enables one to emit point-to-point correspondence in vocal response and the reinforcement is correspondence and auditory feedback	Stimulus-stimulus pairing [52] [53] [54] [55]
	New Learning Possibilities: With parroting, one has the ready topography that creates possibility to induce functional mands and tacts by shifting the reinforcement	
Echoic-to-Mand	A verbal behavior cusp that enables one to emit point-to-point correspondence to other's vocal stimulus when the specified object is the reinforcer as distinguished from parroting. First instances of speech as verbal behavior for contract reinforcement	Echoic-to-Mand [56] Rapid Motor Imitation Approach (RMIA) [57] [58]
	New Learning Possibilities: Echoic to mand establishes the cusp that leads to building a repertoire of mands where the reinforcer is specified for contact functions.	
Echoic-to-Tact	A verbal behavior cusp that enables one to emit point-to-point correspondence to other's vocal stimulus in tacts where the reinforcement is social contact.	Echoic-to-Tact [56] Rapid Motor Imitation Approach (RMIA) [57] [58] Social reinforcement or contact reinforcers that distinguish tact contact reinforcement from contract reinforcement [59] [60]
	New Learning Possibilities: Echoic to tact is the beginning of social contact reinforcers and is necessary for more complex social reinforcement	

Continued

Independent Mand	A verbal behavior cusp that enables one to emit verbal operants that occur under conditions of deprivation and specify their reinforcers.	Speaker Immersion Protocol [61]
	New Learning Possibilities: Independent mands allow one to mediate his/her environment. The emission of this cusp marks a significant step toward one's individual independence. The child who emits independent mands is not verbal yet.	
Independent Tact	A verbal behavior cusp that enables one to emit verbal operants that occur under non-verbal stimulus control and are reinforced by social attention.	Intensive Tact Protocol [60] [62] [63] [64] [65] [66]
	New Learning Possibilities: Independent tacts allow one to recruit adult social attention as a reinforcer under social learning conditions. Sets the stage for conversational units and self-talk conversational units, say/do correspondence and BiN. Necessary for further advancement in the social functions of verbal behavior as well as the joining of listener and speaker.	
Intraverbal	A verbal behavior cusp that enables one to emit vocal response that is different from the vocal antecedents of others. may enhances component composite and composite component derived relations, inherent in young children's aloud self-talk [68]	Say-Do Correspondence and Self-Talk [67] [68]
	New Learning Possibilities: Intraverbal is a component of the conversational units and allows one to answer questions in academic studies and more importantly, to emit social responses with others. The acquisition of intraverbal is one of the key prerequisites for BiN.	
Transformation of Establishing Operations across Mands and Tacts	A verbal behavior cusp that results in the emergence of the untaught function after mastery of one function with the corresponding establishing operations. Prior to this, words leaned in a mand function do not automatically result in the tact function, or vice versa.	Multiple Exemplar Instruction [69]
	New Learning Possibilities: The child will no longer require direction instruction for the untaught functions.	
Autoclitics	A verbal behavior cusp that enables one to emit autoclitics under different mand/tact conditions without direct instruction.	Multiple Exemplar Instruction [11] [69] [70]
	New Learning Possibilities: The five types of autoclitics allow one to describe, qualify, quantify, manipulate, and relate to tacts and mands. With the establishment of a correct reinforcement history in place, the entire structural unit with the tact and autoclitic, the mand and autoclitic functions a tact or mand.	
Textual Response	A verbal behavior cusp that enables one to emit correspondence between textual stimuli and vocal responses.	Auditory Matching for Textual Responses Protocol [71] Read and Do Correspondence [72] Conditioned Reinforcement for Books and Acquisition of Textual Responses [73]
	New Learning Possibilities: The see-say relation expands individuals' verbal communities beyond auditory stimuli, and introduces print stimuli as verbal. See-say responses can become fluent and include comprehension.	

writing, and solving complex relations) possible as extensions of the joining of observing and producing responses. Table 4 lists the advanced verbal developmental cusps and corresponding protocols on joining of listener and speaker responses that enable the child to become fully verbal.

Table 3. Verbal behavior developmental cusps that are new learning capabilities.

New Learning Capability	A capability allows a child to learn *in ways* that the child could not before (*i.e.*, see and do, observing others receive reinforcement or corrections, or exposure). Children contact the reinforcers that are now embedded in the stimuli as conditioned reinforcers.	
	Metamorphosis Status: Chrysalis-Butterfly	
Capability	Description	Protocol Procedure & Research
Generalized Imitation	A verbal behavior cusp and capability that enables one to "see" and "do" untaught novel actions without being directly reinforced by instructor [77] [78] [79] [80]. The correspondence between seeing and doing is the reinforcer [3] [46] [81].	Early research did not establish rigorous evidence of generalized imitation [78] until the development of the Mirror Protocol [77] [82] [83]. This is because correspondence between seeing and doing become the reinforcer. This, in turn creates an observational stimulus control for learning the topography of a behavior.
Generalized Imitation Absent	Imitation responses require direct instruction and are reinforced by prosthetic reinforcement. (Prosthetic reinforcers are those that are not the natural result of the response. For example, receiving money for singing or a token for correctly imitating.) Corrections for incorrect responses require physical prompts. Operants can be formed only by shaping.	
Reinforcement Shift	From direct instructional and prosthetic reinforcement to learned reinforcement for correspondence.	
Generalized Imitation Present	Novel motor responses are acquired through observation and are reinforced by "see-do" correspondence between one's own action and the model. There is no need to teach each operant directly. Corrections for incorrect responses may only require model demonstration.	
BiN	New learning capability allows the learning of word-object relations incidentally. Source of learning 55,000 to 86,000 words by elementary school. Additional stimulus control accrues from additional experience once basic BiN is demonstrated as a result of pairings: BiN and actions, BiN and additional auditory stimuli, olfactory stimuli, and tactile stimuli enter the BiN "frame." Critical cusp that allows children to learn from demonstration and observation, critical repertoire for inclusion success These cusps are the sources of slow and fast mapping. [28] [52] [75] [88] [89] Learning multiple relations from one experience: Stimulus Equivalence [89] Multiple types of relations such as opposites, comparatives, deictic, Relational Frame Theory [4]	Multiple Exemplar Instruction [84] [85] Intensive Tact Protocol [60] [62] [64] [65] [66] Conditioning stimuli for observing responses as fundamental source for the onset of the echoic as the learned reinforcer for BiN [44] [86] [87]
BiN Absent	Children require direct instruction to learn new language, *i.e.*, they must be directly reinforced or corrected in order to acquire new language. [31] [84]	
Reinforcement Shift	From direct instructional reinforcement to learned reinforcement.	
BiN Present	With BiN (and the other cusps that join the speaker and listener within the skin) one becomes fully verbal. Children learn language incidentally. They can observe a vocal and visual stimulus as a listener and emit the same response as a speaker, without being directly taught. As such, they can be taught differently through antecedent stimuli, rather than only through instructor consequences. Children are taught through model demonstration instruction and rather than through feedback instruction only. Research suggests that BiN is an essential to the formation of complex cognitive behavior and reading comprehension [51] [90].	
Observational Learning	A verbal behavior cusp and capability that enables one to learn from observing the instruction of other receive as feedback. Reinforcements for correct responses and particularly corrections for incorrect responses must be observed. [91]	Children can now learn from receiving learn units via peer-yoked contingencies, peer tutoring, and peer monitoring, response boards, choral responding, video presentations [91]-[97]

Continued

Observational Learning Absent	Children require direct instruction to acquire new operants and cannot benefit from observing others receive consequences. Child may not survive in large student-teacher ratio classroom setting. It is likely that the presence of this cusp is essential for learning success in general education classes [31].
Reinforcement Shift	From direct instructional reinforcement to vicarious stimulus control for consequences received by others.
Observational Learning Present	There are four different types of observational learning [91]: Observational learning for performance: one changes behavior from the delivery of vicarious reinforcement to others; Observational learning for acquisition of new operants: one learns through indirect contact with the contingencies of reinforcement and correction feedback; Observational learning for conditioned reinforcement: one expands one's community of reinforcement without direct pairings or instructor conditioning procedures Peer attention: one demonstrates active observations of peers and changes one's behavior based on the observations.

Research from Kuhl and her colleagues [6] [7] [8] shed light on associating neural commitment to evaluate language development. It is likely that the interplay between neuroscience and the science of verbal behavior could illuminate on more timely and detailed measures of the metamorphosis upon the acquisition of new developmental cusps and capabilities (*i.e.*, BiN). A close look at the brain activities before and after the establishment of verbal behavior developmental cusps can identify particular experiences that affect brain behavior and behavior outside the skin leading to a more complete understanding of the role of experience in language and social development, as well as validate instrumentation. Transdisciplinary collaboration between neuroscience and verbal behavior development may provide more insights in how to propel the desired metamorphosis process, or to reverse one's environmental adversity, and/ or native disability.

3. Coda: Bidirectional Operants as Behavioral Metamorphosis

The quality of change in verbal functionality which results from the onset of bidirectional operants as the joining of the speaker and listener needs to be addressed. Our research has led us to believe that the transformation which occurs is comparable to that of metamorphosis in biology. In pursuing this hypothesis, we follow Skinner [12], Catania [13] [14] [15] [16], and Donahoe [17], who as mentioned above, have provided strong arguments for the functional similarities between natural selection in phylogeny and selection by reinforcement during ontogeny. In his review of a collection of papers concerned with major developments in evolutionary biology during the 150 years since the publication of Darwin's *On the Origin of Species*, Donahoe [18] comes to the conclusion that "our understanding of the details of selection by reinforcement is arguably at least as complete as was Darwin's understanding of natural selection" (p. 256).

What is metamorphosis? From the Greek. "meta" for "change" and "morphe" for "form", metamorphosis as a biological process is extreme life-stage modularity

Table 4. Verbal behavior developmental milestones: Joining of listener and speaker responses.

Verbal Milestones: Joining of Listener and Speaker Responses Metamorphosis Status: Butterfly		
Self-Talk conversational units in fantasy play (speaker as own listener within the skin made overt)	*New Learning Possibilities*: Self-talk is a key developmental stage, from both the verbal behavior and cognitive and developmental psychology perspectives. Self-talk may be a prerequisite to other bidirectional operants such as BiN [3]. Skinner [1] proposed that self-talk spoken aloud is a precursor to covert behavior as Lodhi and Greer [68] demonstrated. As children acquire audience control, the behaviors move from overt to covert. Young children often emit self-talk conversational units during pretend play.	
Conversational Units	A verbal episode in which both parties function s a speaker and a listener in one single episode [99] Skinner's [1] verbal episodes Advanced intraverbal responding	Social Listener Reinforcement Protocol [68] [99] [100] [101] [102]
	New learning opportunities: Children who emit conversational units are reinforced as a listener and speaker. Children who do not emit conversational units may respond to intraverbals initiated by a peer or adult (*sequelics*), or will emit mands, but will not initiate intraverbals or may not emit tacts to peers. When children emit conversational units, they have reinforcement for listening to a peer or adult, and ask questions so that they can listen. Thus, procedures to induce conversational units must teach reinforcement for listening and create the correct establishing operations for listening [3] [100] [101] [102] [103]. Conversational units are hallmarks and a primary measure of social behavior. Conversational units include spoken and non-spoken verbal exchanges. Many of the important social components are non-vocal but verbal.	
Say-Do Correspondence	A verbal behavior cusp that enables one to function as a listener to their own verbal behavior and follow the directions given to him/herself.	Correspondence between saying and doing protocol [67] [103]
	New learning opportunities: Say-do correspondence is the beginning of the rotation of listener and speaker roles within one's skin. Conversational units typically demonstrate say and do correspondence.	
Audience Control	A verbal behavior cusp that leads one to engage in different verbal responses in the presence of different audiences.	Social Listener Reinforcement Protocol [1] [3] [100] [101]
	New learning opportunities: Children with audience control emit certain behaviors and verbal responses in the presence of peers that differ from responses that when they are alone or in the presence of adults. Behavior changes in ways that are sensitive to the reinforcing and punishing contingencies of a given audience, hence social awareness.	
BiN Accrues from Listening to a Story Read by Others or Reading	A cusp that allows one to acquire incidentally the name of a stimulus through listening to a story or reading such that they can emit the name in the speaker or listener functions without direct instruction.	Word-picture matching discrimination [51]
	New Learning Opportunities: Children learn names of educational stimuli through listening to a teacher read aloud.	
Conditioned Reinforcement for Observing Books	An individual who has conditioned reinforcement for observing books will choose to look at books during leisure time. This cusp includes behaviors such as turning pages, looking at pictures, and emitting tacts. It is an empirical test of "reading readiness."	Stimulus-Stimulus Pairing Protocol [74] [104] [105] [106] [107] [108]
	New learning opportunities: Accelerates learning to textually respond and comprehend. This is a foundational cusp for textual responding (see and say) and textual responding with comprehension. The child can be introduced to phonetic reading instruction, expanding their verbal **behavior** community to print.	
Textually Responds at 80 Words per Minute	Individuals emit textual responses under the control of print stimuli. They become fluent readers when they can respond at 80 words per minute, beyond a simple see-say relation.	Fluency Training Protocol [3] [109]
	New learning opportunities: When readers are fluent, they can comprehend what they are reading. However, comprehending what is read is not necessarily an outcome of textual responding. The listener within the skin must be engaged simultaneously in listening to the textual responses. Moreover, Conditioned Seeing appears to be a component [104] [105]	

Continued

Responds to Own Textual Responding as a Listener	The child who responds to his own textual responding as a listener can listen to him or herself reading and comprehend.	Multiple Exemplar Instruction across Auditory and Visual Components of Reading Responses [3]
	New learning opportunities: This cusp is the foundation for covert reading comprehension.	
Print Transcription	A verbal behavior cusp that enables one to write with point-to-point correspondence to a printed model (see-write)	Learn Units to Establish Transcription [112]
	New learning opportunities: Foundational cusp for establishing the need to write	
Transformation of Stimulus Function across Saying and Writing	This cusp allows individuals to acquire stimulus control such that they can learn in one topography (saying) and emit the behavior in the other topography (writing), and vice versa. For example, a child learns to spell vocally (*i.e.*, C-A-T is cat) and can also write CAT. This cusp, with BiN and observational learning of new operants, is critical to success in a general education environment.	Multiple Exemplar Instruction Across Saying and Writing [34] [105]
	New learning opportunities: The vocal verbal topography and written verbal topography are joined.	
Dictation	One hears words and produce in print (hear-write)	Instruction to Establish Dictation [109]
	New learning opportunities: Foundational cusp for establishing the need to write	
Read-do Correspondence	Reading governs responding such that one can follow written directions	Reader emersion [3] [72]
	New learning opportunities: The child can follow simple directions in a written topography, serving as a foundation for more complex reading comprehension. This cusp establishes the learned reinforcement functions for technical reading as well as the obvious discriminative functions.	
Textual Responding Joins BiN Repertoire	Print stimuli are also joined to the listener and speaker responses joined in BiN [3]	Word-Picture Matching Discrimination [51] [110]
	New Learning Capability. Children can now read as print stimulus control acquires all of the properties of the spoken word without the constraints of time. The read word results in conditioned seeing [111] [112]	
Textual Responses Function as Auditory Conditioned Reinforcers	Listening to a story is reinforced by one's own speaker responding	MEI Across Auditory and Visual Components of Reading Responses [51] [113]
	New learning opportunities: Overt textual responses become covert	
Technical Writing Precisely Affects Reader's Behavior	This cusp allows a writer to affect a reader such that the reader can produce the writer's desired outcome.	Writer Immersion Protocol [114] [115] [116] [117] [118] [119] [120]
	New learning opportunities: Technical writing precision is the beginning of sophisticated algorithmic writing.	
Aesthetic Writing Affects Emotions	This cusp enables one to write to evoke emotions such as laughter or sadness.	Writer Immersion Protocol [114] [115] [116] [117] [118] [121] [122]
	New learning opportunities: Writing to affect a reader's emotions is truly social and the basis of novels, poetry, and lyrics. Further, a writer can affect a reader across generations, expanding their verbal community.	
Writer Self-Editing	Reader and writer/editor rotate within one skin	Multiple Exemplar Instruction across Reader and Writer Repertoires with a Peer-Yoked Contingency [119] [120]
	New learning opportunities: The writer becomes an effective editor by reading the text as the target audience thereby increasing the probability that the behavior of the target reader will be affected by the writing.	

Continued

Verbally Governed Behavior from Print Stimuli	This cusp enables one to read and complete complex operations as a result of algorithms. *New learning opportunities*: Learn how to do new things through reading, which can lead to new experiences and the establishment of new reinforcers	Need to Read Using Learn Units in Writing [113] [117] [118] [120] [121] [123]
Verbally Governing the Behavior of Others by Producing Print	This cusp allows one to affect the complex behavior of others through writing. *New learning opportunities*: Teach others how to do new things through writing, such as writing a scientific publication.	Writer Immersion [113] [114] [115] [117] [118] [123]

and means that a single genome produces at least two highly distinctive morphological and behavioral phenotypes which occupy very different habitats. From a quantitative perspective, nearly all of the species on earth—butterflies, bees, beetles, ants, moths, flies, and wasps, as well as many marine invertebrates, amphibians and fish—undergo dramatic phenotypic remodeling during development. Metamorphosis is thus ubiquitous throughout nature and has evolved repeatedly in the history of multicellular life. A number of comparative biologists convened a good decade ago to discuss the phenomenon of metamorphosis [124], compared it across various taxa in the animal kingdom, and came to the conclusion that metamorphosis was a component of organismic ontogeny. Of particular interest to the present discussion was the finding that, despite considerable differences in the definition of the term, apparently no distinctive life-cycle transitions comparable to metamorphosis in insects (see caterpillar to butterfly) had been documented in mammals.

In her treatise on *Developmental Plasticity* and *Evolution* [125], considered by some as the most important book about evolution since *The Origin of Species*, evolutionary developmental biologist and entomologist Mary Jane West-Eberhard devotes a separate chapter to phenotypic recombination due to learning (pp. 337-352), wherein she focuses on the importance of learning as the origin of novel adaptive phenotypes. West-Eberhard notes that "Most people, including most biologists, probably underestimate the importance of learning in the biology of nonhuman animals" and goes on to say that, "… learning itself has not always received the attention it deserves as a phenomenon of general evolutionary interest" (p. 337). Inspired by West-Eberhard's approach to behavior and learning, a recent paper on epigenetics and the evolution of instincts suggests that in numerous insects, instincts may evolve from learning, and the paper provides evidence that "… the genome responds dynamically to a range of behaviorally relevant stimuli, often with massive changes in brain-gene expression" [126] (p. 26). Based on her extensive research on social insects and comprehensively documented findings from development, physiology and behavior, West-Eberhard's [125] synthesis of evolutionary biology focused on *phenotypic plasticity* has been influential to the argument developed in what follows.

In our research on children with various types of language delays, time and again we have been struck by the profound behavioral transformation which regularly occurs when novel verbal capabilities are induced in these children on the basis of an applied behavior analysis systems approach to teaching [26] [127] combined with Horne and Lowe's seminal account of BiN in language development [75]. The latter authors noted that "… a child, through learning listener behavior and then echoic responding, learns bidirectional relations between classes of objects or events and his or her own speaker-listener behavior, thus acquiring naming—a higher order behavioral relation" (p. 185), and thus provided a first description of what is now terminologically called bidirectional naming or BiN [76]. Given that such bidirectional responding usually emerges untaught once children reared in a language-rich environment have acquired listener, echoic and tacting repertoires, we believe that the bidirectional verbal operant merits special consideration as a potential candidate for behavioral metamorphosis during language development [128].

In his "*Biographical Sketch of an Infant*", it was Darwin [129] again who made a keen observation in one of his own children, and it serves as an excellent starting point for the introduction of the bidirectional operant as an instance of behavioral metamorphosis from the perspective of evolutionary developmental biology. Darwin wrote:

> "At exactly the age of a year, he made the great step of inventing a word for food, namely mum, but what led him to it I did not discover. And now instead of beginning to cry when he was hungry, he used this word in a demonstrative manner or as a verb, implying 'Give me food'… I was particularly struck with the fact that when asking for food by the word mum he gave to it (I will copy the words written down at the time) 'a most strongly marked interrogatory sound at the end'. He also gave to 'Ah,' which he chiefly used at first when recognizing any person or his own image in a mirror, an exclamatory sound, such as we employ when surprised. I remark in my notes that the use of these intonations seemed to have arisen instinctively, and I regret that more observations were not made on this subject. I record, however, in my notes that at a rather later period, when between 18 and 21 months old, he modulated his voice in refusing peremptorily to do anything by a defiant whine, so as to express 'That I won't'; and again his humph of assent expressed 'Yes, to be sure'… The interrogatory sound which my child gave to the word mum when asking for food is especially curious; for if anyone will use a single word or a short sentence in this manner, he will find that the musical pitch of his voice rises considerably at the close. I did not then see that this fact bears on the view which I have elsewhere maintained that before man used articulate language, he uttered notes in a true musical scale as does the anthropoid ape *Hylobates*" (p. 293).

Darwin [130] had expressed this view six years earlier in his treatise on "*The Descent of Man, and Selection in Relation to Sex*", Vol. 2, as follows:

> "Another gibbon, the *H. agilis*, is highly remarkable, from having the power of emitting a complete and correct octave of musical notes, which we may reasonably suspect serves as a sexual charm; but I shall have to recur to this subject in the next chapter. The vocal organs of the American *Mycetes caraya* are one-third larger in the male than in the female, and are wonderfully powerful. These monkeys, when the weather is warm, make the forests resound during the morning and evening with their overwhelming voices. The males begin the dreadful concert, in which the females, with their less powerful voices, sometimes join, and which is often continued during many hours. An excellent observer, Rengger, could not perceive that they were excited to begin their concert by any special cause; he thinks that like many birds, they delight in their own music, and try to excel each other. Whether most of the foregoing monkeys have acquired their powerful voices in order to beat their rivals and to charm the females—or whether the vocal organs have been strengthened and enlarged through the inherited effects of long-continued use without any particular good being gained—I will not pretend to say; but the former view, at least in the case of the *Hylobates agilis*, seems the most probable" (p. 277).

Of particular interest in this context is so-called "duet-splitting" and "singing" in gibbons (*Hylobatidae*), documented in a field study by Geissmann [131]. Throughout the tropical rainforests of southeast Asia, in many species of gibbons, mated pairs and unmated couples characteristically combine their songs—stereotyped, loud and long sequences of vocalizations—to produce conversational duets, which apparently have the function of advertising territoriality, attracting mates and, once established, maintaining pair and family bonds.

In the *Descent of Man,* Darwin [130] wrote that the human musical faculty "must be ranked amongst the most mysterious with which he is endowed" and hypothesized an intermediate stage of human evolution characterized by a means of communication that resembles music more closely than language—a type of prosodic protolanguage—as a precursor to both modern language and music. This topic, which has always been puzzling to evolutionary biologists, has recently been investigated by Masataka [132] [133]. In a similar vein, theorizing with a view towards 'a more comprehensive understanding of language,' Greer [134] mentions music and dance in addition to verbal behavior and the visual arts as evolutionary outcomes of the ontogenetic selection of separate observing and producing responses and the cultural joining of them (p. 370)—thus setting the stage for the hypothesis proposed here concerning the evolutionary origins of the bidirectional operant as an instance of behavioral metamorphosis in *Homo sapiens*.

In a recent descriptive study in baboons, Boë and colleagues [135] suggest that *Papio Papio* produces vocalizations comparable to human vowels. Employing acoustic analyses of vocalizations coupled with an anatomical study of the tongue muscles and dynamic modeling of the acoustic potential of the vocal tract, the data suggest that baboons, in spite of their high larynx, are capable of producing at least five vocalizations with the properties of vowels, and that they can combine them when they communicate with troop conspecifics. The finding suggests that the last common ancestor of *Homo sapiens* and *Papio papio* may have possessed the anatomical wherewithal for speech—hinting at a much earlier evolutionary onset of vocal verbal skills than heretofore assumed. In an observational study on the use of affiliative vocalizations by wild baboons, Silk, Seyfarth and Cheney [136] recently found that despite their limited vocal repertoire, *Papio ursinus* females were skilled at modifying call production in different social contexts and for different audiences (e.g., vocalizing towards mothers with young infants but not towards females without infants). We may assume that the socially selective production of calls in these female baboons presupposes a complementary selective listening behavior in their female counterparts.

With a view towards speech perception from a comparative perspective, valuable support would be given to the prosodic protolanguage view of the evolution of language if, for example, functional ear asymmetries like those typically found in humans were established experimentally in nonhuman primates. In the first study to document ear advantages for acoustic stimuli in a nonhuman primate species, Pohl [137] found highly significant and reproducible ear advantages in four baboons (*Papio cynocephalus*) for the monaural discrimination of pure tones, three-tone musical chords, synthetically-constructed consonant-vowels (CVs) and vowels in each of the animals with marked individual differences in the direction of ear asymmetry. The ear advantages found in these baboons under monaural conditions resembled those obtained with dichotic presentation in human subjects [138] and thus suggest—especially when considered together with the recent findings [135] on the vowel-like quality of baboon vocalizations mentioned above—that the baboon may provide a valuable nonhuman primate model of functional asymmetry in the central auditory system. In a subsequent study on ear advantages for temporal resolution in the same four baboons, Pohl [139] hypothesized that the temporal resolution which underlies the individual animal's ear advantage for speech perception, would predict an ear advantage in a temporal resolution task to correlate precisely with an ear advantage for the discrimination of CVs that differ in their temporal features. A gap detection task that required the resolution of brief intervals of no noise (between 7 and 20 msec depending on the animal) in bursts of random noise was employed using the same experimental paradigm as in the previous study to test the hypothesis in all four baboons. The findings clearly confirmed the hypothesis in that the probability of obtaining by chance the same direction of ear advantage in four animals under two very different task conditions was less than .01. The results suggest that a single perceptual mechanism based on fine temporal analysis underlies the CV discrimination and gap detection tasks in both humans and baboons and that this mechanism may be asymmetrically organized within the central auditory system of primates. These findings in baboons have potential implications for the evolution of hemispheric specialization for speech perception in man

[140]. We now turn to comparative studies in birds, which throw further light on the argument developed here.

Any attempt to understand behavioral metamorphosis during speech development from a biological perspective is well advised to take note of a few established facts from studies of birdsong development such as auditory feedback in song development [141], the discovery of hemispheric lateralization of song control [142] and functional similarities of vocal learning in birds and man [143] [144]. In a recent retrospective of Marler's pioneering work in the field of birdsong development, Soha and Peters [145] list six basic rules, identified through Maler's extensive experimental and observational research, which underlie the ontogeny of vocal behavior in both humans and white-crowned sparrows (*Zonotrichia leucophrys*). As they are pivotal to the argument under discussion, we summarize these rules here:

1) Exposure to certain sounds (usually the vocalizations of adult male conspecifics) has a crucial impact on song repertoire of adult songbirds.

2) This exposure has the greatest effect during a certain developmental time range, which means that vocal learning proceeds most readily during an early critical period.

3) Vocal learning is guided by species-specific predispositions: young songbirds are predisposed to pay particular attention to the vocalizations of their own species whereas human babies preferentially attend to the speech of their mothers.

4) Both songbirds and babies must hear their own output during vocal development, as auditory feedback guides the matching of this output to what was heard previously.

5) Some vocal learning in songbirds apparently proceeds without external reinforcement. Horne and Lowe [75] suggest this and Longano and Greer [88] report evidence for learned embedded reinforcement as the source of BiN in children.

6) Vocal motor development proceeds in stages: young individuals begin by making vocal sounds that do not resemble those of adults, and even deafened individuals produce the earliest versions of these sounds (subsong).

Kuhl [8] and her associates have pioneered multidisciplinary research on social and speech development in early childhood and compared it with studies of birdsong development. Kuhl [7] notes that "Both babies and birds must… rehearse and refine their communicative repertoires, actively comparing and gradually matching (through auditory feedback) their productions to the sound patterns stored in auditory memory (p. 9645)."

Taken together and combined with the primate data cited above, these findings suggest that a class of operant behavior underwent selection by reinforcement, enabling modular design of a bidirectional behavioral phenotype as a necessary precondition for the evolution of human speech development. In joining the listener and speaker together in the same skin, the bidirectional operant would seem to exemplify the process of complete behavioral metamorphosis. In terms of our visualization from insect ontogeny, if the caterpillar's habitat is the ground, branches and leaves, and the pre-verbal child's world is the immediate physical and social environment, then the butterfly's new habitat is the air and plants and the novel environment of the fully verbal child is the symbolic universe of a verbal community. Whereas the pre-verbal child behaves more like a bright nonhuman primate in its proximate physical and social environment, the child who has acquired BiN or operant bidirectionality becomes a member of a verbal community, which is the equivalent of a novel environment of symbolic relationships. We propose here that the evolutionary prerequisite for that profound behavioral transformation is the ontogenetic selection of separate observing and producing phenotypes and their modular integration into the bidirectional operant through social learning embedded in a human culture. Based on this proposition, we could envisage the gradual approximation of two sub-disciplines of biology—evolutionary developmental biology and developmental verbal behavior analysis—which would lend further support to the idea of a unified model of behavior [125].

Finally, the homologies assembled here of metamorphosis across taxa may someday help us understand the riddle of what paleoanthropologist Ian Tattersall [146] depicted in his unsettling evolutionary account entitled "*Once We were not Alone*", in which behavior and learning play a central role. The story, which we quote extensively because of its significance for the argument developed here, begins by mentioning that we usually take for granted that *Homo sapiens* is the only hominid on Earth—despite the fact that for at least four million years many hominid species shared the planet. What makes us different?

"Business had continued more or less as usual right through the appearance of modern bone structure, and only later, with the acquisition of fully modern behavior patterns, did *H. sapiens* become completely intolerant of competition from its nearest—and, evidently, not its dearest. To understand how this change in sensibility occurred, we have to recall certain things about the evolutionary process. First, as in this case, all innovations must necessarily arise within preexisting species—for where else can they do so? And second, many novelties arise as "exaptations", features acquired in one context before (often long before) being coopted in a different one. For example, hominids possessed essentially modern vocal tracts for hundreds of thousands of years before the behavioral record gives us any reason to believe that they employed the articulate speech that the peculiar form of this tract permits." (p. 62).

The author then goes on to say:

> "We do know, however, that somehow our lineage passed to symbolic thought from some nonsymbolic precursor state. The only plausible possibility is that with the arrival of anatomically modern *H. sapiens*, existing exaptations were fortuitously linked by some relatively minor genetic innovation to create an unprecedented potential. Yet even in principle this cannot be the full story, because anatomically modern humans behaved archaically for a long time before adopting modern behaviors. That discrepancy

> may be the result of the late appearance of some key hardwired innovation not reflected in the skeleton, which is all that fossilizes. But this seems unlikely, because it would have necessitated a wholesale Old World-wide replacement of hominid populations in a very short time, something for which there is no evidence. It is much more likely that the modern human capacity was born at—or close to—*the origin of H. sapiens, as an ability that lay fallow until it was activated by a cultural stimulus of some kind* (italics ours). If sufficiently advantageous, this behavioral novelty could then have spread rapidly by cultural contact among populations that already had the potential to acquire it. No population replacement would have been necessary. It is impossible to be sure what this innovation might have been, but the best current bet is that it was the invention of language. For language is not simply the medium by which we express our ideas and experiences to each other. Rather it is fundamental to the thought process itself. *It involves categorizing and naming objects and sensations in the outer and inner worlds and making associations between resulting mental symbols* (italics ours). It is, in effect, impossible for us to conceive of thought (as we are familiar with it) in the absence of language, and it is the ability to form mental symbols that is the fount of our creativity, for only once we create such symbols can we recombine them and ask such questions as 'What if...?'" (p. 62)

Tattersall [146] ends his account on a memorable note: "We do not know exactly how language might have emerged in one local population of *H. sapiens*, although linguists have speculated widely. But we do know that a creature armed with symbolic skills is a formidable competitor—and not necessarily an entirely rational one, as the rest of the living world, including *H. neanderthalensis*, has discovered to its cost" (p. 62).

Given a certain plausibility, the message in Tattersall's narrative is that if verbal development played a central role in the selection and rapid global dissemination of symbolic behavior in *Homo sapiens*, it will be future innovation in education and learning which comes from the most rapidly developing members of the species, namely children and adolescents, who will help us most to navigate in what the late German sociologist-philosopher Ulrich Beck has aptly called "*The Metamorphosis of the World*" [147]. In this development, the significance of bidirectional operants cannot be overestimated.

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