The Neurological Significance Of Children's Drawing: The Scribble Hypothesis

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Abstract

Drawing is a substantive mental activity. Its defense has been made (Sheridan, 1990, 1997). The Scribble Hypothesis extends that argument, establishing human mark-making as our defining language instinct. This paper posits four neurological reasons for the phenomenon called scribbling. In addition, to clarify the profound significance of little children's scribbles, this paper demonstrates scribblings' physical overlaps with images from art history and abstract mathematical representations of brain activity. This visuo-neurological-mathematical appreciation for scribbling and drawing is important for a multiple literacy education. Scribbling is the wellspring from which speech, reading, and writing flow across sign systems.

Introduction

Only one thing is certain - that written language of children develops in this fashion, shifting from drawings of things to drawings of words. The entire secret of teaching written language is to prepare and organize this natural transition appropriately...Make believe play, drawing and writing can be viewed as different moments in an essentially unified program of development of written language...

Lev Vygotsky, "The Prehistory of Writing," an essay, c. 1930 in *The Mind in Society,* pp. 115-116, 1978.

My dissertation (1990) focused on human mental operations as translations: "If language is approached from the point of view of neurobiology, then language is a system for translating ordered stimuli in certain ways. Stimuli are organized at point of sensory entry (the eye, for instance), undergoing repeated reorganizations, or translations, by cooperating brain systems. Language is continuous with other translation systems. With the whole of biological evolution as its context, language takes its place as a seeking system; language is the ultimate pseudopod reaching for words and images as its nourishment. Language is the outpouching of a central nervous sytem that thinks about itself, using marks" (Sheridan, 1990, p. 198). Like consciousness (Scott, 1999; Wilson, H., 1999; Freeman, 2000), language and literacy are emergent phenomenon with physical requirements In the case of human consciousness, marks are the physical requirement (Sheridan, 1990, pp. 197-8).

The dissertation (1990), the 1997 textbook *Drawing/ Writing and the new literacy*, and twenty years of teaching continue to support the usefulness of drawing to writing. As the child persists in the adult, so drawing persists phylogenetically and ontologically in writing as its underlying mark-making impulse. Neurobiological research makes it increasingly clear that brain systems, including the two hemispheres, are complementary, suppressing each other for functions the other does best to maximize the brain's capabilities (Gazzaniga, 1982, 1985; Hellige, 1993; Miyashita-Lin, E. M., Hevner, R., Wassarman, Montzka, K., Martinex, S., Rubenstein, J. L. R., 1999). By using drawing and writing in complementary mode as an educational strategy, education models and encourages optimum brain activity. Scribbling is the tangled matrix where drawing and writing begin.

The following paper presents the fourfold Scribble Hypothesis: Children's scribbling serves four critical purposes: to train the brain to pay attention and to sustain attention, to stimulate individual cells and clusters of cells in the visual cortex for line and shape, to practice and organize the shapes and patterns of thought, and, through an increasing affinity for marks, to prepare the human mind for a consciousness organized by literacy.

The Four Hypotheses

Hypothesis One: Very young children's scribbling trains the brain to pay attention and to sustain attention, setting up a self-organizing, dyadic feedback loop between the eye/hand and the interhemispheric brain.

It is common to think about very young children's scribbles as large motor practice for as yet underdeveloped fine motor skills or as early attempts at drawing, for instance, the human figure as a "tadpole." Can we move from an anthropocentric position on children's drawings? When they scribble, very little children are not drawing; they are modeling neural systems.

If we think of children's scribbles in three ways, they become intelligible. Children's scribbles act as relevant visual attentional stimuli; they are evidence of basic, underlying, dyadic, back-and-forth, oscillatory, organizational brain mechanisms; and scribbles are the beginning of drawing, reading and writing. Children's scribbles are intelligible to them! Their marks carry meaning. The scribbling child can talk about her marks. Talk about marks is the beginning of reading.

The focus of the Sheridan 1990 dissertation was the connections between drawing and writing. In researching vision, attention, memory and learning, it became clear that sustained visual attention was a prerequisite for learning. Drawing and sustained attention went hand-in-hand. Could drawing be used to train the brain to pay attention and to sustain attention, in so doing, triggering considerable brain power for other activities like writing (Sheridan, 1990, pp. 22-31, 62-65, 86,187-193, 196-91)? Current research supports the 1990 Sheridan doctoral research; selective attention causes synchronous firing of neurons in the visual cortex, unifying input about an object so that we can associate, for instance, the color of a plum with its shape. Synchronous firing also achieves postsynaptic gain, amplifying signals for behaviorally relevant stimuli (Fries, 2001). This gain creates a "halo of attention " for relevant versus distracter objects so that the relevant mental object appears bigger and brighter (Stryker, 2001). Children who scribble are learning to create striking mental events while mobilizing additional mental power for writing and reading.

The visual self-training in attention begun by the infant lying on its back is continued by the upright mark-maker. Children's mark-making reinforces call-and-response behavior between hand, eye, and brain set in motion by the unfolding of protein, by the evagination of the neural tube, by the watery womb, and by mothers or other devoted caretakers. Rhythmic brain activity acts as a coordinator, a unifer, a comparator (Churchland, and Gazzaniga in Sheridan, 1990), constructing consciousness as integrated awareness (Stryker, 2001; Fries, P., Reynolds, J. H., Rorie, A. E., Desimone, R., 2001). Mothers and drawing play large parts in encouraging rhythmic brain activity.

Babies' brains are tuned for certain frequencies and oscillation rates by their mothers (Conlon, 1976, 1974, 1975, 1978; Tomatis, 1963, 1970, 1971, 1991; Wolff, 1967, 1968; LaFrance, 1982; Kranowitz, 1998; Kendon, 1982; Gardner, Kay, 1990; Chapple, 1982; Harris, 1998). Babies encourage these maternal exchanges simply by being adorable (Hrdy, 1999). Caretakers of babies instinctively use "motherese," or high-pitched tones. Motherese calibrates the infant brain for higher frequencies, including human speech.The uterine walls provides low-light conditions and muffled sound. The eyesight and hearing of the fetus are organized by low-frequency aural and visual stimuli. Higher aural and visual frequencies are part of a baby's life outside the womb (Hellige, 1993).

Mothers and other caretakers not only use high-pitched tones, but they naturally engage in dialogic exchanges like peek-a-boo. Games train the brain for cooperative exchanges, including a communicative life (Hellige, 1993; Condon, 1966, 1974, 1975, 1978, 1979, 1981,1982; Daubenmire, 1982; Stern, 1982; Beebe, B., Gerstman, L., Carson, B., Dolins, M., Zigman, A., Rosensweig, H., Faughey, K., Korman, M., 1982). Pinker argues that "motherese" does not teach children language in the sense of providing a syntactical model for deep grammar (Pinker, 1994, pp. 39-40). Pinker suggests motherese is more like animal vocalizations, a "melodic rise and fall" for "approving... prohibiting... for directing attention... for comforting" (pp. 278-279), adding that children can learn language without "standard motherese" as a grammatical model (p. 290). Pinker also maintains that the arts are "biologically useless" (1997, pp. 521-526). This paper proposes that the neural function of motherese and the arts is teaching and practicing self-synchronizing, self-integrating gestures.

Hypothesis one proposes that drawing takes over where motherese and peek-a-boo leave off. Children's scribbles train the visual brain attentionally for the higher, sharper frequencies necessary for discriminating edges (or where one object ends and another begins, or figure/ground distinction), as well as for dialogic exchanges between brain systems, and between the self and the world. Goleman calls these lessons empathy (1994).

The balance and the complexity in four or more dimensions between oscillatory activity and neuronal synchronization in human brains must differ from other language-using creatures, and it must differ because of marks, since marks -- not song nor dance nor vocalizations nor gestures nor pheromones -- make human behavior unique. Children's natural instinct to self-organize via drawing must inform the relationship between firing patterns and levels, training the brain for integrated exchanges of information via marks. Literacy is very old. It began when a thumb pushed into clay. It began by dragging a toe through sand. It rests upon the same instinct as sucking and reaching and peek-a-boo. This deep instinct claims infant scribbles as part of its ancient repertoire of self-constitutive activities.

Hypothesis Two: Very young children's scribbling stimulates individual cells and clusters of cells in the visual cortex for line and shape.

In *Inner Vision: An Exploration of Art and the Brain* (Oxford University Press, 1999), professor of neurobiological studies at the University of London, Dr. Semir Zeki, makes the argument that artists, especially modern, non-representational artists like Piet Mondrian, Kasimir Malevich and Alexander Calder, intuitively used line and form and color and motion in ways that optimally stimulated specialized cells in the visual cortex.

Hypothesis Two extends Dr. Zeki's hypothesis: very young children's scribbles as clusters of lines provide intuitive practice for their visual cortices, especially for cells which specialize in line orientation. Dr. Zeki's hypothesis allows us to conjecture, in addition, that artists like Jean Arp, Joan Miro, and Juan Gris responded strongly to young children's art because of its basic visual cortical attraction as line and form, not for higher cortical appeal like naive content.

Desmond Morris has written about the drawings of chimpanzees (1962) as self-rewarding activities. Irene Pepperberg writes about the communicative ablilities of a gray parrot named Alex (1999). Heather Busch and Burton Silver have written a playful book about the art work of cats (1994), including a theory of feline aesthetics. We may share an aesthetic with chimps and cats because our visual systems require similar stimulation for line and shape discrimination, or even because emotions trigger similar brain waves, and we may share speech with parrots, but we don't share literacy, and literacy makes the difference in how our brains operate.

Children's drawings as circles, spirals, triangles and rectangles extend hypothesis two as follows: very young children's marks are the substrate for a multiple literacy that rests on geometry. Before children's marks become numbers or the ABC's, their marks explore Euclicean and non-Euclidean geometry. They explore the dot, the line, the circle, and the spiral. They come up with the simplest abstract representations for thought (Stephen M. Kosslyn, Walter J. Freeman, personal correspondence, March 2001). Why? These shapes must be part of the structure and process of human thought (Churchland, 1986; Scott, 1999; Sheridan, 1990; Shastri, 1999; Seife, 2000).

By drawing these shapes, children do two things: they organize their thinking more coherently, that is, they draw more controlled dots, wavy lines, scallops and spirals, and they prepare their brains for Euclidean and non-Euclidean geometry including Riemannian space and fractal dimensions.

If very young children *are* spontaneously drawing the shapes of thought, and if these shapes *are* closer to geometry than to other explanation systems, and if books about the art work of patients afflicted with schizophrenia and migraine headaches (Sacks, 1993, pp. 273-278) overlap with research on the fractal geometry of nature (Mandelbrot,1977; Hofstadter,1980; Gleick, 1987; Peitgen & Richter, 1986; Pickover, 1990, 1996), then Platonic forms (Euclidean *and* non-Euclidean -- dodecahedra *and* the Mandelbrot set) are not the distillate of the phenomenological world (i.e., not Zeki's "stored representations," 1999, p.40), but inherent, genetically determined, "pre-existing" structures and processes with neurological, biological, geological and cosmological significance. Hypothesis two validates Plato, Zeki (1999), Sacks (1992), and Kaufman (1995).

Hypothesis Three: Very young children's scribbles help them practice and organize the shapes or patterns of thought.

Children's scribbles function neurally in three ways: they represent thought, they make thought, and they refine thought. Scribbles function as central motor pattern generators for antiphonal body exchanges including bipedal locomotion, or walking, running, and swimming (Wilson, F., 1999, p. 205). Secondly, the circles and spirals and waves children draw are at least abstract mathematical representations of brain activity (Stephen Kosslyn, personal correspondence, March 2001; Wilson, H., 1999; Walter J. Freeman, personal correspondence, March 2001). Whether children's scribbles are abstract or concrete representations of the shapes of thought, scribbles provide practice with such shapes, and may streamline neural operations in some directly kinaesthetic manner.

Sylvia Fein's comprehensive book, *First Drawings: Genesis of Visual Thinking* (1993), shows that children -- and humankind -- use the same visual language: the point, the line, the circle, the spiral, the maze, the mandala, the mandorla, the rectangle and the triangle. Geometry -- sacred and profane, Euclidean and non-Euclidean -- is an elemental neural/visual language.

Research by Walter J. Freeman (1991, September, 2000) at the University of California at Berkeley with the phase portraits of animals' brain patterns showed that brain waves modeled as loose spirals become tightly organized spirals at the moment of recognition. The brain waves of monkeys, rats, and humans are similar enough (Wilson, H., 1999) to allow us to generalize from research on smell recognition to children's drawings. Hypothesis three reinterprets children's drawings including their scribbles and humankind's art, neurologically. Squiggley lines (eeg's or electroencephalograms) and nested spirals (phase space portraits) are the hand's intuition of the linear and non-linear activity of the brain. "In nerve propagation, an essentially one-dimensional phenomenon, an impulse, travels along an axon, releasing and consuming energy as it goes. When the equations describing this process are used in two or three spatial dimensions, a variety of interesting physical processes emerge, including several sorts of spirals" (Alwyn Scott, personal correspondence, March 12, 2001; Scott, 1999). The Fibonacci series demonstrates the power of the spiral as an organizing biological principle. Scroll waves in slime molds, scroll rings which underlie the processes of fibrillation in a malfunctioning heart reveal the importance of the spiral in living systems (Scott, March 12, corresponance, 2001: Scott, 1999).

Children's scribbled spirals are significant mathematical/neurobiological intuitions.

As Stephen M. Kosslyn, psychophysicist at Harvard observed, "Spirals and circles are abstract representations of the activity of populations of neurons; I don't think they can be taken literally in any sense. But the person to ask is Walter Freeman" (personal correspondence, March, 2001). Walter J. Freeman, neurodynamicist at Berkeley agreed, "These geometric figures don't exist in brain dynamics or elsewhere in biology, only in mathematics where we use them to think about things. Your children are practicing for that." Dr. Freeman added that the spiral I found so significant in the phase portrait of a creature recognizing a smell in his 1991 research was "selections of startings or endings like children just warming up, and the full blown pictures you were asking me for as additional examples are from such a high dimension that they don't make sense to us." That is, the phase portrait I read as a spiral was only incidentally a spiral and an actual phase portrait might or would be unintellible. Dr. Freeman added that children go beyond spirals. "For them they are first steps. For you and me they are metaphors" (personal correspondence, March, 2001). The fact that Dr. Freeman believes that children's brains are designed for mathematical thinking is hugely important. Why have we organized education so that mathematics is set apart from our natural unfolding as mark-makers? Still, I hold to this mappability I see between scribbles and neural models, and I believe that little children's spaghetti-like scribbles are intuitive phase portraits like those made by folding linear traces of brain waves onto themselves for display (Freeman, March 2001, in personal correspondence, supported this statement), and that other kinds of scribbles have direct neural significance, too.

Neural processes like short-term memory, resistance to change, decision-making and intentionality have correlates in higher-order behavior (Wilson, H., 1999, pp. 72, 73, 86, 92; Freeman, December, 2000). Hypothesis three proposes that the geometric shapes children draw do exist in brain dynamics and are significant at higher cortical levels. Throughout history, the triangle has been used by architects, engineers, mathematicians, scholasticists and artists. The neural substrate for the triangle is the simplest three-neuron excitatory/inhibitory feedback loop found in the tail of the lamprey eel. One of its higher order effects is Hegel's thesis/antithesis/synthesis principle. The neural basis for synthesis is the cross inhibitory interneuron betweeen the excitatory and the inhibitory interneurons. Thesis, antithesis and synthesis are basic neural operations.

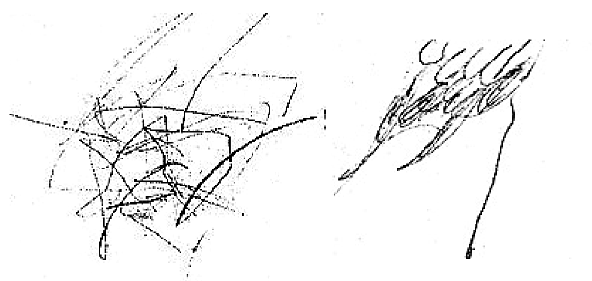
Figure 1
Josef Lee Guptill

Josef Lee Guptill, age 1.5 years, and Parker Allen, age 2.5 years, show us that young children's scribbles spontaneously generate brain-like patterns as modeled mathematically, and include proto-triangles.

On the 26th of March, 2001, Josef Lee Guptill, age 1.5 years, came to my farmhouse in Maine for dinner. He burst into tears the minute he came in the door and, pointing piteously, indicated that he wanted to leave. After some time, outside in the dark with his mother, Josef was carried back in. He continued to cry until I handed him a long pencil, and held a little pad of paper under its tip. The second the tip of the pencil touched paper, Josef stopped crying. Like the sun coming out through dense fog, Josef's tear-stained face broke into a smile as he moved the distant tip of the pencil over the paper, looking straight at me. Later, on his mother's lap, Josef produced the scallops and the tight spirals with their initial tall spike and following tall, wider spike, followed by a long, straight descending line you see below.

Figure 2
Josef Lee Guptill, Age 1.5 Scribbles

Drawing #1 Drawing #2



Parker Allen, age 2.5, produced a drawing of his pregnant aunt (who is my daughter) with the caption, "This is the baby. Do you see it?"

Figure 3
Drawing #3; Parker Allen, Age 2.5, Scribbles

It is possible to explain Josef's and Parker's scribbles in neural terms. As small sections of the spinal cord of the lamprey eel are capable of generating rhythmic bursts of spikes acting as pattern generators for the entire tail, and as pieces of holographic images, planaria-like, will generate a whole image (Talbot, 1991), so we can use these scribbles to reconstruct little children's mark-making repertoire in neural terms.

Drawing #1: Josef's drawing done without looking is self-regulatory, self-organizational, or calming behavior: mark-making as thumb-sucking. Adults use scribbles, or doodles in this way, too. The gesture, not the marks (Josef was looking at me while scribbling), is the significant action. As soon as Josef looked at this haystack of lines, cells for line orientation began firing in his visual cortex. Several accidental proto-triangles are evident.

Drawing #2: Josef's scalloped lines represent passive, endogenous properties of living cell membranes or cell biophysics. Josef's spirals represent phase spaces for non-linear activity with more than two dimensions, including spikes or neural bursts. The long line that grows exponentially out of the lower right of Josef's drawing stands for trajectories in chaotic behavior. Very prominent peaks seen in Josef's two long, down-pointing spikes are indicative of either periodic or quasiperiodiac, non-chaotic behavior.

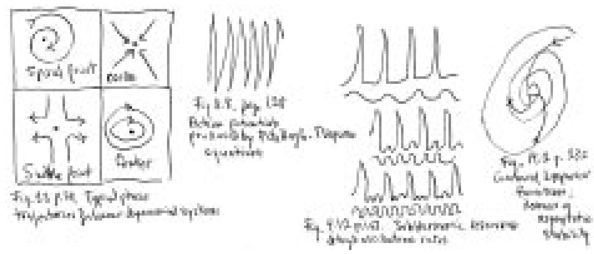
Drawing #3: Parker has a taller, thinner more angular initial series, very much like representations of neural spikes, then turns into lines in various attitudes which provides exercise for neurons in the visual cortex which specialize for line. Parker also includes a triangle -- practice with proto-geometry -- then swoops into nested curving lines in an overlayed phase portraits of the spaghetti variety. There are no spirals. Discrete dots are arranged neatly above, beside, and below the matrix of marks, indicating Parker's deep appreciation for the power of the single neuron. Two long descending lines are included, one an offshoot of the proto-triangle. These may be trajectories in chaotic behavior, too.The fact that Parker's drawing is captioned is important: the caption indicates that Parker is reading.

As my daughter, an English major commented, an analysis of a single line by Emily Dickinson can go on for pages. I am simply applying the tools of close analysis to children's scribbles, contending that they are freighted with neurological/mathematical meaning, too.

Visual support for these findings can be found throughout the book *spikes, decisions and actions* (Wilson, H., 1999). The author reproduces by hand some of these images of brain activity. The reader can judge how closely Josef's and Parker's scribbles resemble these mathematical models. Such imperative and lively marks must be more than motor pattern generators -- as important as such generators are. We are not lamprey eels. Scribbles are evidence of an instinct for literacy, and literacy lets us model our minds. This makes us very different from lampreys.

Figure 4

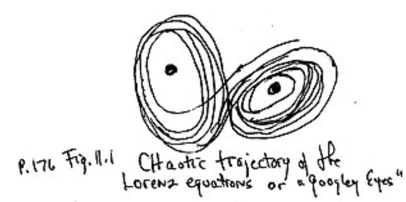
Drawings Of Mathematical Models Of Brain Function From *spikes, decisions and actions,* copyright H.R. Wilson, 1999. Drawn by author with permission of Oxford University Press.



If someone were to draw two connected, reversing spirals like the ones below (Wilson, H., 1999, p. 176), we might say that the drawing recreated the chaotic trajectory of the Lorenz equations in the three-dimensional state space plotted with two of the unstable steady states. If chaotic behavior is part of our brain operations, as well as part of squid and aplysia neurobiology (Wilson, H., 1999), why shouldn't humans draw chaotically?

Figure 5

"Googley Eyes" Or Chaotic Trajectories. Drawings Of Mathematical Models Of Brain Function From *spikes, decisions and actions,* copyright H.R. Wilson, 1999. Drawn by author with permission of Oxford University Press.



Art history provides many images of unstable steady states or chaotic trajectories -- especially in connection with hallowed or sacred places and things. For examples of connected spirals rotating in opposite directions, or reverse meanders, see Fein (1993, p. 27), stone 4,000 b.c.e., Gallows Outon, Scotland; curbstone, Newgrange cemetery, Ireland, 5000 b.c.e.;the Greek double spiral at the nucleus, 3000b.c.e., limestone ceiling Orchomenos (p. 31); curved Scottish serpentine balls, 4000-4500 b.c.e. (p.34); Moche stirrup vessel, Peru 1200-1800 b.c.e., cycladic pottery, 4500 b.c.e., Sicilian pottery 3300 b.c.e. (p. 35), carpet page, the Book of Durrow, Ireland 1350 b.c.e. (p. 37); a similar repertoire of attached, reversing spirals can be found in Gimbutas, 1989. Gimbutas calls these ancient, repeating patterns" the grammar and syntax of metalanguage" (1989, p. xv). The substrate of this metalanguage is neural. Visual perception and visual imagery are related (Kosslyn, S.

M., Thompson, W. L., Alpert N. M., November, 1997: Kosslyn, May, 1999).

Figure 6
Reversing Spirals From *First Drawings:Genesis of Visual Thinking,* copyright S.Fein. 1993, permission of S.Fein, and reversing spirals from *The Language of the Goddess,* copyright M.Gimbutas, 1989, permission of HarperCollins Publishers, copied by the author

If children are accessing neural patterns, their drawings may capture strange attractors and chaotic landscapes, showing us how connected they are to coherent systems. Coherent systems are embedded; they are linear-non-linear like the wave-particle theory of light (Zajonc, 1993). The evolutionary usefulness of chaotic brain activity may be creativity based on "the rapid generation of many unpredictable alternatives" (Wilson, F., 1999, p. 184). What a crisp definition of an over-used word! Philosophically, neural chaos may make it impossible for any of us to predict our own behavior in detail (p. 184), still, "the old free-will versus determinism controversy in philosophy may have its resolution in neural chaos" (p. 184). As a small mark may entirely change a drawing, so a small thought may entirely change entrenched thoughts. Change is built into primate brains (Wilson, H., 1999). Chaos does not make us unique, but it makes us innovative and not entirely knowable.

Hypothesis Four: Very young children's scribbling encourages an affinity for marks, preparing the mind for its determining behavior: literacy.

Art history suggests that homo sapiens began making significant marks as long as 40,000 years ago (masses of lines in soft clay, Fein, 1993). Writing is said to have begun with pictographs (Sumerian or Egyptian) about 3,000 b.c.e. Rotated and stylized pictographs standing for sound emerged about 3,000 to 2,000 b.c.e. Prehistoric cave drawings circa 17,000 b.c.e included proto-literate marks (Sheridan, 1997), allowing us to push writing back another 13,000 years.

Studies of the arm bones of hominid fossils shows the hands attached to such arms could have grasped small tools more than four million years ago (Wilson, F., 1999). The hand that holds and manipulates small tools is capable of drawing. If drawing antedates not only writing, but speech, then the neural infrastructure for speech was in place 100,000 years ago (p. 185). Increasingly, linguists are placing gesture and sign on a continuum (Acredolo & Goodwin, 1996). Babies' signs can be a rich language. Children's gestures help them solve math problems (Bower, 2001, p. 172). Adult math professors gesture when they talk about mathematical problems; the gestures "correlate with verbal expression of certain abstract mathematical concepts" (Wilson, H., 1999, p. 285). Scribbles are visually guided mental strategies, too, and they point the way educationally: let children gesture, speak, scribble, draw and write their way into understanding. Scribbling is the mark-making gesture of the very young brain embarking on speech and literacy.

Imagine Lascaux: the mind is awhirl with non-verbal thoughts. The hand grasps a stick and makes a mark.The creator looks at the mark. Others look at it. What to make of it? As Roland Barthes has observed about this dilemma, text helps us to read drawings *at the right level* (1985, 1978, 1964). The cave painting "The Chinese Horse" painted in Lascaux, France between 13,000 and 17,000 years ago includes double dashes on the right and a hovering tectiform above. These marks may have focussed the meaning of the painting of the horse (Sheridan, 1997, p.32).

Figure 7
"The Chinese Horse," Lascaux, permission Yvonne Vertut, copyright Jean Vertut
All rights reserved, Jean Vertut, Yvonne Vertut.

Conclusion

At this point in educational history, no child can be considered apart from its brain. Neurobiology gives us a new way to look at children, including their scribbles. Whether scribbles are pictures of neural activity or motor organizers, they are marks with a destiny. What other biophysical entity generates marks to explain and extend the parabolic burstings in its brain?

A stochastic linear/nonlinear self-regulatory feedback loop drives random di-polar electromagnetic field reversals in the earth's poles (Banerjee, 2001). It also drives us, heartbeats to brain waves (Pickover, 1990, 1996; Freeman, January, 2000) to scribbles. Children's wavy lines and spirals are significant evidence of dynamic systems operating across physical and mental levels in the human body and the world. Very little children's squiggley lines and spirals may not yet be significant pictorially nor be readable as numbers or text, but they are significant neurally. They demonstrate the complex, embedded action of thought destined to be organized by marks.

With no instruction, children move from scribbles to drawings. These may be "conceptual" drawings or "schematic" drawings or representational drawings. We do not know what they are to the child. We do know that the child's drawings represent meaning, and that they follow logical, syntactical rules (Tyler, 1999). With instruction, children's neurologically rule-driven repertoire of marks expands; they produce letters and numbers and graphs and equations and music. Literacy must be biologically adaptive or it would have faded out long ago. We and our marks have co-evolved. Complex thought is adaptive, intellectually and emotionally (Csikszentmihalyi, 1993). The fact that many artists return to the abstract scribbles of early childhood may mean the work we did as scribblers persists as pleasing and useful and signficant to the adult central nervous system. Central pattern generators are necessary to all rhythmic behavior, including conversations, love-making, parent-child interactions, and the dialogue with the self.

This paper introduces a new theory and practice of education: Neuroconstructivism and Drawing/Writing. Both focus on the child's brain as the active agent in learning, sharing the Piagetian and Vygotskian understanding that the mind of the child is qualitatively different. Knowledge, intelligence and morality spring from the child's actions, and this "child-action" has the quality of being playful and experimental. Neuroconstructivist theory extends the Piagetian/ Vygotskian model; not only do children construct knowledge, intelligence and morality but they construct their brains through thought and action. This thought and action is both visual and verbal. As parents and educators we must keep firmly in mind that the networks children construct determine present and future capabilities for visual and verbal thought and action (Sheridan, 1997, pp. 492-3). Remediation helps, but it is not reconstitutive; a shriveled amygdala is effectively ruined for rage control and short-term memory (Gladwell, 1997). Physical abuse, psychological abuse, visual deprivation, speech deprivation have long-term neurological consequences. Early childhood is extremely important and family plays a tremendous role in the growth of the child's visuo-verbal brain -- as does early education. This position strongly counters Bruer, 1999, *The Myth of the First Three Years.*

A neurological appreciation for scribbling elevates apparently aimless marks to the level of instinctual self-training as a literate and inventive thinker. If the infant is, in truth, the "scientist in the crib" (Gopnik, A., Kuhl, P., Meltzoff, A., 1999), testing its environment from the moment of birth, is it any less likely that young scribblers are artists, writers, mathematicians, and musicians in the making? Can any activities so instinctual, so universal, so compelling be inconsequential? Such a conclusion flies in the face of evolutionary theory.

Very young children's scribbling is significant and literacy is a determining factor in human consciousness and in human intelligence. The illiterate child or adult is disadvantaged. Illiteracy is non-adaptive.

Children are at risk for failure on many levels (Kindlon, 2000; Kranowitz, 1998; Kegan, 1994; Healy,1999; Pipher, 1994; Pollack, 1998; Kabat-Zinn, 1990; Gudron, 2000; Greenspan, 1999; Greene, 1998; Freed, 1997; Fite, 1996; Bloom, 1987; Barry, 2000). Still, the drawing instinct persists. Wholeness through marks is possible, as wholeness through music is possible through antiphonal exchanges (Campbell, 1997; White & Epston, 1990; Britten et al, 1975; Cameron, 1992, 1998, 1999; Lamotte, 1994; Edwards, 1979, 1987; Ganim, 1998, 1999; Elbow, 2000; Brennan, 1993; Bennett, 1999; Bruner, 1986; Goldberg, 1986; Kandinsky, 1914; Greenspan, 1999).

Mark-making creates a third environment between family and the influential peer group (Harris, 1998), allowing self-definition on a brain's own terms. Mark-making creates a heightened experience of "flow" when our skills are just equal to the challenges we set ourselves (Csikszentmihalyi, 1993) allowing us to experience the "highs" our brains crave without dangerous drugs.

Because children's marks are so important to brain growth, the Scribble Hypothesis adds drawing to parenting.

Drawing is child's play. It is an art school activity. It is the draftsman's skill and the mathematician's window on complex thought. It is the medieval monk's worship. Drawing is a foundational instinct and ability. It should be the bedrock of courses like "Developing Reading Abilities in Children" or "Introduction to Writing for Children and Adults" or "ESL Combined Skills."

Once we stop thinking about little children's scribbles as meaningless, and young children's drawings as inadequate representationally, we can think about them from a neurological point of view, grasping what is special about human visuo-verbal consciousness.

Coda for Parents and Teachers and People in Business

If geometry is an early and persistent visual language, parents and teachers might pay more attention to the part geometry plays in our lives. If synchrony characterizes successful internal and external exchanges of information and enegy in the brain and in the world, we might take more advantage of call-and-response conversational and managerial modes in the living room, the classroom, and the boardroom. If fractal dimensions and feedback loops are responsible for mental inventiveness, surely fractals provide design cues for our lives.

Currently, modes of parenting and methods of education prevent the development of most of the marks a child could generate during its mental life. If parents and teachers let children scribble and talk about scribbling, draw and talk about their drawings, write about their own drawing, and talk about their writing, asked only to read their own drawings and writings, first, before they are asked to read anyone else's, children will move more naturally into writing and reading. Learning delays and disabilities, short attention spans and a host of behavioral problems may clarify themselves as what happens when chilren are separated from what their brains have evolved to do in the course of the normal, natural developmental unfolding of a marks-based intelligence.

The mark-making *and* the talking are important. Until the child knows what the hand has drawn, the work of the hand -- and thus of the mind-- remains an unspoken mystery.

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