THEORY

A four-stage hierarchical model of image construction and drawing production: Evidence from visual hallucinations, development and pathologic regression in art

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Abstract

A four-stage hierarchical model of image construction is proposed. Stage 1 involves amorphous or scribble fields of light, color, and spots; Stage 2 involves abstract geometric shapes; Stage 3 schematic recognizable objects; and Stage 4 represents three-dimensional realistic images. A similar four-stage model is also proposed for drawing an image. Evidence to support our model of the visual construction of an image is based on phosphenes and various other kinds of visual hallucinations. Evidence to support a similar four-stage model for drawing an image is based on the development of children's drawings and from drawings of adult artists suffering from mental pathologies or Alzheimer's disease. Findings from brain research supporting both models and implying underlying neurological functions and locations are also cited.

Keywords: model, image construction, image drawing, hallucinations, Alzheimer's, mental pathologies

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In this paper we propose that a perceptual image is normally processed—that is, constructed—in the human visual system through what can be considered four qualitatively different hierarchical stages. We also propose that the same four stages are involved in the physical production of an image, such as drawing a picture. After providing evidence for a multi-stage hierarchical construction of visual images, we relate these stages to artistic development in children and to changes in the depictive style of artists suffering from neurological and/or psychiatric pathology. The model involves hierarchical processing from (a) initial sensing of light and color in amorphous or point fields to (b) processing of perceptual representations of geometric shapes to (c) cognitive schematic construction of objects to (d) a normal synthesized 3-dimensional realistic representation. This hierarchical model is consistent with neurophysiological findings that suggest serial processing in ascending the neuraxis (Bar, 2003; Hawkins, 2004; Jackendoff, 1987; Prinz, 2000), yet also assumes a parallel form of processing within each functional level of the hierarchy.

It is important to note that this is not a model of how the perception of color/light, or geometric shapes, or schematic objects—or complete scenes themselves—presumably takes place. Instead, these stages are assumed to take place probably using some kind of parallel processing, but otherwise how they take place is not treated. Thus, this paper outlines a gross structural model of the stages or processes of image construction, and considers the implications of such a hierarchical structure for how an image is constructed in the final perceptual representation. It then relates this to such phenomena as children's drawings, visual hallucination, and regression in drawing by people suffering from serious pathology such as Alzheimer's disease.

One consequence of the model is to show how a patient's art can be directly relevant to medical practice, since the model proposes that for certain patients their art is an intelligible expression of underlying neurophysiology.

The Model: Perceiving or Constructing an Image

Stage 1. The first stage or level, which we term sensory, is characterized by amorphous color fields and scribbles. The visual appearance or phenomenology of Stage 1 consists of a field of light or color; also included are spots or dots of light that occur in a haphazard pattern—that is, the dots are not arranged in such a way as to allow straight lines or other recognizable shapes. Scribbles—that is, patterns made up of many heterogeneous lines without any recognizable shapes or objects—are also representative of Stage 1. Such scribble patterns are interpreted as another form of amorphous or inarticulate visual field. Scribbles are commonly made by children using a relatively sharp-pointed pencil or crayon; however, if instead they were given a relatively wide brush, their scribbles would look much like an amorphous color field. Stage 1 images such as these are produced by children when they first begin to draw. Familiar examples from modern art of images whose visible aspects are also assumed to have been primarily completed in Stage 1 include the typical color-field paintings of Mark Rothko, the familiar drip paintings of Jackson Pollock, and many of the works of Cy Twombly, Franz Klein, and many abstract expressionists.

To describe a painting as at Stage 1 (i.e., sensory: amorphous or color field; or scribble) in no way criticizes the artwork or implicitly equates it with the work of a child: On the contrary, the greater aesthetic and cultural significance of the artist's work based on higher-order processing is assumed. We only illustrate image types, nothing more.[1]

Equally, when we characterize the processing of a visual stimulus as being completed at any given stage—especially in the case of paintings by adult artists—we do not mean to imply that the stimulus is not also processed at higher levels. Rather, we posit that that stimulus is not processed any further in terms of the image properties characteristic of the stage in question. It is well known that network processing that engages the cortex brings lower visual material into a complex framework involving higher-order visual associations, in addition to neural networks that engage memory, recognition, interpretations, meaning, and other contextual information. We also assume (see Zeki, 1998) that each stage represents both a level of completed processing and a level of perception.

Stage 2. The second stage, which we call perceptual, is characterized by geometric lines and patterns (e.g., triangles, ellipses, composites of such shapes, etc.), but without any recognizable objects. These shapes, we assume, involve some prior processing at Stage 1. Examples of such Stage 2 processed images are the typical works of such artists as Victor Vasarely, many by Wassily Kandinsky, Piet Mondrian, Kazimir Malevich, and

1 Note that when we use the expression "Stage 1, 2, 3 or 4 image" we are using shorthand to refer to an image where the visual processing of the stimulus, according to the model, has been essentially completed at the designated Stage.

Josef Albers; and countless more recent artists whose paintings are of simple or complex abstract geometric shapes.

Stage 3. This stage consists of cognitive-schematic (i.e., cartoon-like) objects. Stage 3 is distinguished from Stage 2 by the clear appearance of recognizable objects; however, these objects are schematic and generally flat—such that major cues to depth (e.g., shading, linear perspective) are absent. We believe this level to be legitimate and important, although it has not been given much attention in the experimental literature. Examples of Stage 3 images include many works by Pablo Picasso, Fernand Leger, and other cubists. Marcel Duchamp's *Nude Descending a Staircase* is a well-known representative of this stage, and there are many others. A recent Stage 3 artist would be Keith Haring; and, of course, almost all cartoons and caricatures represent what we are calling Stage 3.

Stage 4. This, the model's final stage of perceptual construction, is characterized by comprehensive and realistic 3-dimensional scenes. Stage 4 consists of the images characteristic of normal visual experience. While there are additional stages and processing beyond Stage 4, we maintain that these involve post- or extravisual neural functions—such as language, for example, or judgments about beauty as identified by Kawabata & Zeki (2004)—but these are beyond the scope of the present discussion. Examples of Stage 4 images include all typical realist portraits, landscapes, and still lifes.

It is important to note that this model proposes that there are only four qualitatively different kinds of visual image—one type at each stage. We assume that most natural, three-dimensional visual experiences involve the earlier constructive use of the three "simpler" stages. A few natural stimuli are presumed to cease being perceptually processed at early stages—for example, perception of the sky and the ocean are normally finished by Stage 1, although the moon and the sun (when present) bring in some of Stage 2. In terms of the model, the perceptual construction of many human artifacts (such as art, buildings, or cartoons) is often completed by Stage 2 or 3.

In addition, we understand that the stages of image processing are mental (i.e., perceptual, experiential, and/or phenomenological) in character (see Zeki, 1998), and most likely reflect complex activity of brain networks that engage hierarchical logic rather than just a specific localization in the visual neuraxis. Nevertheless, we posit that there is plausible neurological evidence for some stage localization as presented below.

Evidence for Stage Localization

Pressure phosphenes. Perhaps the simplest evidence for the first two stages can be observed when gentle pressure is applied to the closed eyes (Oster, 1970; Tyler, 1978). When this occurs, it is common to first observe changes in the brightness of what was an all-black field, followed by points of light (often colored) on a black or almost black field and, finally, grids or gratings or fields of squares, which are often colored. Presumably, pressure applied to the front of the eyes initially color-stimulates retinal elements, then the lateral geniculate, and then areas of the primary visual cortex. Most likely, after this level, visual stimulation achieved by pressure is no longer effective and dissipates.[2] In other words, simple activation of the initial transductive and conductive elements in the visual pathways (without photic input) is sufficient to generate early-stage responses. But the absence of additional stimuli (and differential engagement of amplifying and rectifying elements in the retina) means pressure on the eye is insufficient to elicit higher-stage processing activity.

Electrically induced phosphenes. The most systematic investigation of phosphenes has involved the use of mild electric current (Höfer, 1963; Knoll, Höfer, & Kugler, 1966; Knoll, Kugler, Eichmeier, & Höfer, 1962; Knoll & Welpe, 1968; Seidel, Knoll, & Eichmeier, 1968). In these experiments the participant was blindfolded, and low-level electrical stimulation was applied to the lateral orbit. Such electrical stimulation invariably elicited a visual response—electrical phosphenes—in all observers, who were then instructed to draw examples of their visual experiences. Analyses of hundreds of such reports were classified into 15 fundamental types, as shown in Figure 1. We refer to these as the Munich taxonomy of phosphenes (noting that the studies were conducted in Munich, Germany).

With the exception of spots, all of the reported phosphenes induced by electrical stimulation can be categorized as Stage 2 shapes in accordance with the present model. The intensity and frequency of electrical stimulation that elicited a given phosphene shape was not consistent across subjects, although it was consistent within a subject. The similarity of these basic shapes to most children's basic scribbles (see Figure 3) was noted by Kellogg, Knoll and Kugler (1965).

Sensory Deprivation. Some of the earliest descriptions of perceptual experience indicative of the

2 For the history of the study of, and speculation about, such eye deformation-induced phosphenes, see Grosser and Hagner (1990).

underlying visual stages can be found in the sensory deprivation literature. In these studies, male college students spent time in a cubicle in which sensory experience was markedly reduced. The participants wore translucent goggles so that all visual input appeared as a relatively homogeneous field of light. They also wore gloves and cardboard cuffs; the latter extended from the elbow to below the fingertips, in order to reduce tactile stimulation. Auditory stimulation was limited by continuous background noise created by fans and air conditioners and by a U-shaped rubber head pillow that acted as a sound baffle. Participants lay on a bed in a cubicle for 24 hours a day, with interruptions only to eat and for toilet breaks. Most could tolerate sensory deprivation for only two or three days before finding the experience unpleasant and terminating involvement in the experiment.

Of the 29 participants, 25 reported some form of visual hallucination. Heron (1961) observed that hallucinations typically progressed from simple to more complex: The first symptom would be a lightening of the visual field, followed by dots of light or lines; then geometrical figures and patterns, often composed of reduplicated figures, followed by isolated objects against a homogeneous background; and, lastly, full-blown scenes would appear. The reduplicated geometrical figures were sometimes described as wallpaper patterns. Actual figures or objects without a background included images of "a row of little yellow men with black hats on and their mouths open […] a German helmet … [and] … a procession of eyeglasses marching down the street" (Heron, 1961, pp. 6–33). The figures were often described as cartoonish. Complete scenes and landscapes were the least frequently reported hallucinations.

We believe that these reports describe all four stages or levels of visual processing as proposed. The lightening of the visual field and points of light (i.e., earliest experiences) show Stage 1. In pressure phosphenes, these experiences often involve de-saturated colors (although color was not addressed or reported in these experiments). Sensory deprivation-induced hallucinations at Stage 2 are represented by reports of lines and geometrical figures and patterns (e.g., wallpaper patterns); Stage 3 visual phenomena include cartoon-like figures (cf., "rows of little yellow men with black hats and their mouths open"); and Stage 4 is represented by more integrated scenes, especially those described as landscapes. In addition, it should be noted that these perceptions occurred in the predicted order (i.e., from simple to more complex), and that each higher stage was less frequently reported than the previous stage—with the highest stages being reported by only about 20% of participants.[3]

Vernon and McGill (1962) also present a multi-level description of sensory deprivation-induced hallucinations. However, the researchers limit these effects to a 3-level process: Level 1 consisted of flashes of dimly glowing or flickering light without shape; Level 2 hallucinations were more complex and were geometric (e.g., squares, circles, lattice-work); and Level 3 were complex and contained integrated and/or animated scenes that were highly structured and rich in detail. While Levels 1 and 2 are similar to our model's first 2 stages, Vernon and McGill group into a single category (their Level 3) what we distinguish as Stage 3 and Stage 4 processing.

Bonnet Syndrome. A well-known medical phenomenon involving visual hallucinations is the Charles Bonnet Syndrome. This syndrome describes the spontaneous appearance of complex visual hallucinations in adults who are without psychopathology. These hallucinations are experienced primarily by older patients who have visual deficits, especially at the retinal level. Reduction in vision due to vascular pathology in the periphery as well as in visual areas of the brain (e.g., A17–19) is associated with the syndrome. Schultz and Melzack (1991) noted that there is considerable literature indicating that the loss of visual input to the brain as a result of pathology can be a cause of visual hallucinations, and they suggest that these "represent a visual analogue of the phantom limb phenomenon—that is, experience generated by brain activity in the absence of sensory input" (p. 809). Cole (1992) has noted the similarity of sensory deprivation-induced hallucinations to those of Bonnet syndrome: He considers that the absence of visual stimulation in Bonnet's patients is analogous to the absence of external stimuli in sensory deprivation.

Bonnet syndrome hallucinations are "usually colorful, well-formed images that are detailed and sharply in focus even if they appear at a distance" (Schultz & Melzack, 1991, p. 810). The objects seen are quite varied, with images of people and animals being especially common. Examples include, among others, "a brightly colored circus troupe" and "large chickens wearing shoes" (Schultz & Melzack, 1991, p. 811).

A review of the different images, as provided by Schultz, Needham, Taylor, Shindell, and Melzack (1996), reveals that 23% of subjects reported simple light flashes, colored light, and black dots or "bugs". These reports describe what we categorize as Stage 1

3 The results cited here are summarized from the works of Bexton, Heron, and Scott (1954); Heron (1957); and Heron (1961).

images. A further 12% reported formed geometrical shapes or elaborate designs—what we consider to be Stage 2. G. Schultz (personal communication, August 16, 2000) reported that Bonnet's patients frequently described some of their images to be like "cut-outs" and stated that the term "schematic" seemed appropriate for such descriptions. Thus, we conclude that many of the complex hallucinations reported by Bonnet's patients are what we classify as images characteristic of Stage 3: mainly flat, schematic, and cartoon-like.

Further evidence for Stage 3 images can be found among descriptions of Bonnet's Syndrome that appear in the earlier French literature. As discussed by Flournoy (1901), Charles Bonnet's descriptions of hallucinations in his original patient, his grandfather Lullin, were described as being like tapestries or as tableau scenes—terms that suggest rather flat, schematic images. Also reported were fabric patterns, flowers and leaves, a white satin background with black shapes, and circles—all like images on paper. A frequently reported hallucination was of blue handkerchiefs sometimes called squares (or *carreaux*).

In discussing Bonnet's syndrome, de Morsier (1967) describes one 19th century patient who saw "posters on the walls of his room" (p. 681); another 20th century subject reported flat figures of men and animals. De Morsier (1969) also reported patients' descriptions of hallucinations as being like handkerchiefs or black and white images (as in movies), as well as other descriptions equally suggestive of the schematic, flat, cartoon-like qualities proposed for Stage 3 processing in our model.

Schultz et al. (1996) stated that the face of a person or complex scenery was reported by over 70% of Bonnet's patients. It is clear from these reports that the images were often quite realistic, and thus can be considered Stage 4 (i.e., 3-dimensional) according to our model.

It may be somewhat difficult to accept our claim that individuals can have direct phenomenological access to the neurological structures involved in the internal stages of visual processing; however, the aforementioned evidence certainly implies that this is indeed the case. In normal visual experience, the underlying abstract elements at each stage are assumed to be completely captured by the properties of the natural, external visual stimulus, but in the absence of any externally initiated visual stimulation, humans appear to have the ability to consciously experience the internally initiated activity of the underlying visual elements. This accounts for the hallucinations that are expressed at a particular stage.

The Model: Producing the Image

The model as described thus far posits processing of input beginning at a sensory level and progressing to the construction of a phenomenally realistic image at Stage 4. There is, however, another aspect of the model in addition to input processing—namely, that in order for a person to draw, there must also be an output-processing mechanism. After all, when a three-year-old child begins to draw, the child is presumably seeing the world at Stage 4 with all of its 3-dimensional realism. Likewise, many adults with normal 3-dimensional perception are unable to draw or paint at a level as sophisticated as Stage 4. Therefore, although apparently all adults can at least make stick figures (i.e., early Stage 3 images), we consider that the problem—both for children and many adults—is an inadequately developed output or "drawing" module; in particular, they have poor or non-existent Stage 4 output responses.

We propose central nervous system (CNS) mechanisms that entail output strategies that allow a person to draw a picture. Such proposed output mechanisms are presumably linked to the input-processing system but in many ways also remain distinct. Various theorists have proposed that the deficits in children's drawings are not caused by conceptual inadequacies—and certainly not perceptual limitations—but instead are the result of production or drawing-skill deficits (see Cox, 1992, 1993; Freeman, 1980; Freeman & Cox, 1985; Milbrath, 1998).

Perhaps at the highest level of input processing the cortical area devoted to image recognition is roughly similar to the primary speech recognition area (i.e., Wernicke's). If so, we posit that the image drawing module would be analogous to the speech production area (i.e., Broca's). We suggest that this output-processing model is hierarchical, and that it is organized in the same four stages as the input-processing model. There is research to support a distinction between the neural substrates of visual perception and those underlying visual control (Goodale, 1996; Goodale & Milner, 1992). This distinction may involve complex interactions between spatial vision and output responses. If both input- and output-hierarchical models exist, then distinct development of these substrates might be evidenced in both perception and drawing patterns during ontogeny; and, further, CNS insult could differentially affect either or both networks to evoke different patterns of perception or drawing—either separately or possibly at the same time.

Developmental Evidence

Children's drawings. Systematic investigations and theorizing about children's drawings have been carried out by many. One especially comprehensive study was published by Rhoda Kellogg in 1970 in which she described progressive development based upon observation of thousands of drawings made by children from a wide variety of cultural and ethnic backgrounds (Kellogg, 1970). She concluded that, on average, children's drawings move through the four developmental stages as posited by our model. At first there are only scribbles (see Figure 2). The next level involved "basic" scribbles—Kellogg identified twenty of these basic scribbles or, as we call them, basic forms. After the dot, which we place at Stage 1, the first simple forms are straight lines of vertical, horizontal, and diagonal orientation, then a curved line, then multiples of these elements; this is followed by a roving open line; then a zigzag, a loop, a spiral, and circles (as shown in Figure 3). Typically, most of these basic forms are apparent by the time a child is three years old.

A few comments about the basic forms are in order at this point. Although Kellogg claimed that dots and then lines of different orientation were the initial basic elements, one should keep in mind that not every child develops all the basic forms before moving to the next stage or level, and there can be considerable overlap in stages. In Kellogg's description, then, the elements to develop after basic forms are diagrams—examples of which include the cross-shape, square, circle, triangle, an X-shape, and a closed figure that is asymmetric, usually a roving line coming back on itself.

Kellogg strongly emphasized that the level of simple geometric forms develops after scribbles and prior to simple schematic pictorials. Recent scholarship of children's drawings has been critical of the proposed universality of Kellogg's more complex geometric shapes, especially mandalas, radials, and other complex forms. However, the presence of simple forms similar to Kellogg's are accepted as a necessary precursor to even early figure-type drawings, the first pictorials of children (such as Figure 4a). Howard Gardner, for example, a cognitive psychologist with an extensive knowledge of children's drawings, recognized four basic stages of development (Gardner, 1973, 1980). He labeled the four as scribbles, forms, things (simplified objects) and, finally, attempts at realism. More recently, Malchiodi (1998) reviewed much of the published work on children's art and reported stages compatible with the present model, namely: scribbling, basic forms (simple abstract geometric shapes), human forms, and early schemata, followed by more developed schemata and, last, realism. In children's art, the schematic representation of the human form rapidly becomes more detailed and specific, and soon includes hands, arms, and legs (see Figure 4b); other elements are sometimes added, for example clothing to indicate gender differences. This level of representation is often called early pictorialism. At about the same time, the child begins to draw trees, animals, and buildings. As noted, all of these theorists propose that all children go through these stages, arriving at a pictorial level at which drawings are flat and schematic. (See also Milbrath, 1998). Only a small number of children, especially the most talented, move on to our Stage 4, where more realistic, 3-dimensional drawing involving the use of depth cues commonly makes its appearance.

In Figure 5 this hierarchical process in the development of children's drawing is summarized by Kellogg in a way that even she considered oversimplified, but which nevertheless captures the basic idea clearly.

It is important to note that drawing (at least up to early pictorialism) is not the result of the child looking at something and then attempting to draw it; rather, the child seems to be attempting to draw some pattern or schema that exists as an internal mental construct. Much of the time, children's drawings do not appear to be based on some object in their external visual environment that they are trying to reproduce, but instead are determined by a pre-existing schema and by the drawing itself. This process is similar to how an adult constructs a doodle.

Within the framework of our model, therefore, evidence for Stage 1 is found in the early scribble drawings and in the use of dots; Stage 2 is shown in basic diagrams and other more complex geometric shapes and designs; and Stage 3 is represented by early and late pictorialism with its flat, cartoon-like and very schematic representation of objects.

There are a few curious exceptions to this approximate developmental sequence—for example, the well-known case of Nadia, an autistic child who demonstrated extremely advanced depictions of depth and realism almost from her first efforts at drawing at age three or four (Winner, 1982). In this case, however, Nadia's unusual ability was probably closely related to her autism and thus cannot serve as a representative contradiction to the normal progression of stages. Nadia had eidetic imagery combined with a very limited ability to generalize, or form abstractions, or classify objects into categories (Selfe, 1977). Winner (1982) noted that Nadia "could not match pictures of the same objects unless both pictures represented the object in the same orientation" (p. 186). Hence we conclude that her case is more of an outlier, as the bulk of the evidence supports a four-stage model of visual and output processing in children.

Pathological Evidence

Alzheimer's disease. Alzheimer's disease is a slow and progressive degenerative condition involving the hippocampus and cortico-temporal networks that are primarily involved in short-term memory consolidation and cognitive processes. Given the protracted nature of this pathology, it is possible to obtain drawings from the same patient over the course of the disease. Within the premises of our model, as a degenerative condition affects the networks that subtend general perceptual or perceptual-motor function, the patient's drawing should evidence regression through Stages 4 and 3 to Stages 2 and 1 of the model as higher processing function is successively lost. An example of this is presented in Figure 6, which illustrates regression in an Alzheimer's patient who was an artist (Cummings & Zarit, 1987). The first drawing (Figure 6a) is a naturalistic representation and can be described as primarily a Stage 4 image. The second drawing (Figure 6b) shows the schematic Stage 3 exemplified by a clear reduction of depth. The last drawing (Figure 6c) reveals strong geometric Stage 2 properties, although minor aspects of Stage 3 still persist. Another obvious case of stage regression in a female Alzheimer's patient (Wald, 1984) is shown in Figure 7 (a, b, c). We do not assume that every drawing made after another will necessarily be more regressed that the previous drawing, since the disease can stabilize, and can sometimes even appear to improve for short periods of time; but over a period of a year or so regression should be apparent.

In her book on art by Alzheimer's patients, Ruth Abraham (2005) identifies four characteristics of their artwork: simplification, fragmentation, distortion, and perseveration. The first is a term that could be used in a general way to describe regression to our Stage 1; however, we describe simplification more specifically. We do not deal with the second and third descriptors, fragmentation and distortion, although both of these can be understood in our model as the natural consequence of moving from a naturalistic scene through Stages 3 and 2 to Stage 1. The last characteristic, perseveration, seems quite reasonable, but we have nothing to say about this temporal response.

Another recent representation of regression can be seen in the self-portraits of the professional artist William Utermohlen, who was first diagnosed with Alzheimer's disease in 1995. Figure 8a, from 1996, shows considerable realism and depth via shading. By 1997, however, much depth and realism has dropped out and the work shows a primarily schematic, Stage 3 face with a good deal of Stage 2 geometric patterning in the background; and in 1999 the face is now primarily Stage 1. He died of the disease in 2007.

Some final support comes from the late paintings of the prominent abstract expressionist artist Willem de Kooning.[4] In de Kooning's earlier and most representative period, his works typically showed recognizable parts of a woman's body, especially aspects of the face, with the rest of the work being without pictorial content. However, a few of his works during this mature period were also without any imagery or even geometric emphasis. He was diagnosed with probable Alzheimer's disease around 1980, and he also suffered from the effects of alcoholism based on many earlier years of heavy drinking. He continued to paint until mid-1990 and eventually died in 1997. From the perspective of the present model, all of de Kooning's works of the late period are without any Stage 3 schematic imagery and without any systematic geometric patterning (Stage 2). All are either wandering line-like works, usually with strong red, blue, yellow or orange, and occasional green color in the lines or in the shapes created by such relatively thick, wandering lines. A few others are just dark areas of color without any line properties. In short, all of his quite late paintings appear to be at Stage 1. In a modest way, some of his late works were prefigured by aspects of some of his pre-Alzheimer's paintings but they are, in general, quite distinctive. This interpretation is not to deny that they have artistic merit. De Kooning was an extremely talented and innovative artist but he seems to have been driven down to this lowest level, according to the model, by his Alzheimer's condition. Nevertheless, even here he was able to express an intriguing aesthetic. Louis Wain, a much smaller artist who suffered from severe mental pathology, discussed below, produced his most artistically interesting works when he had regressed from Stage 4 to earlier stages. Again, as mentioned earlier, the stage level of a work is not a comment on its aesthetic value.

We also expect that a similar representational regression might be found in some stroke patients or other brain-damaged artists such that the greater the (network hierarchical) effect of the CVA (i.e., cerebrovascular accident), the greater the regression of the patient's ability for visual representation. We posit that progressive recovery from the damage would co-

4 For information on de Kooning's life and late works see Storr and Garrels (1997). Examples of his late paintings made in the late 1980s can be found easily online under his name and "late paintings."

incide with a reversal of such change(s) and advancement to higher stages of processing and representative output. One example supporting this proposal is found in a description of the progressive recovery of a brain-damaged artist provided by Zaidel (2005).[5]

Psychiatric pathology and recovery. Before we address psychiatric pathology and recovery, it is important to summarize the earlier research on psychiatric hallucinations conducted by Horowitz (1964). In this study, subjects reported examples of spots, grids, wavy lines, circles, radiating figures, and similar Stage 2 types of hallucinations, although amorphous specks (Stage 1), schematic shapes of a faucet and animal heads (Stage 3), and realistic animate objects such as a parent or sibling (Stage 4) were also described. When interpreting the reported hallucinations, especially those from anxious and depressed psychiatric patients, Horowitz contends that:

> It was necessary to persist beyond initial verbal descriptions […] and insist that the patient describe and draw what he had seen. Initial descriptions of "vicious snakes" might then be drawn and re-described as wavy lines. In one case the patient's description of "Two armies struggling over my soul" arose from the subjective experience of seeing moving sets of dots. (p. 513)

In short, psychiatric patients (and probably non-psychiatrically disordered individuals) often provide fairly complex narrative interpretations of what are, in fact, much simpler visual percepts.

Serious psychiatric conditions can also result in a loss of mental capacity that damages adults' ability to draw. Thus, we can expect that the severity of psychiatric disturbance will show up in changes to the stage or level of a person's drawing. Prior to any evidence of mental pathology, a typical adult should be drawing at either Stage 3 or 4 depending on his or her skill. As a mental condition becomes more severe, regression through the stages should become evident—analogous to the effects of Alzheimer's disease. A number of examples support this possibility; perhaps best known is the work of the artist Louis Wain. During his normal adulthood he was well known for his paintings and drawings of cats, which appeared in many illustrated English periodicals (Dale, 1991). These were realistic, and the cats were often shown in humorous situations, implicitly mimicking human interactions. After some years as a successful artist, however, Wain became mentally disturbed and was hospitalized for schizophrenia. The rather well-known series of five drawings that demonstrate the regression in Wain's work can be reliably found under his name on the internet (see Cardoso, n.d.). In the series of his cats presented by Cardoso, the last example is devoid of any recognizable content and from the perspective of the present model is essentially only a Stage 2 image. (Note that Cardoso's use of the word *stage* is different from ours.) It is clear that the early signs of deterioration are present by the changes that can be seen between the first and third drawings: The third "cat" shows considerable loss of depth (via shading), and there is the emergence of much schematic, cartoon-like imagery. Loss of depth is the major cue to movement from Stage 4 down to Stage 3.

There is no reliable evidence that the usual series of Wain's cats was actually made in the order shown, but that seems somewhat irrelevant. Over the years, schizophrenia—like most mental pathologies—can wax and wane for a given patient, even if the general tendency is one of decline over time. In any case, the deterioration in the images is obvious, and Wain's changes are supported by the other examples shown here, where the mental state of the artist at the time of each drawing is known. It is interesting to note that when Wain's images have been shown to students in various university classes by the first author (P. C. V.), it is often remarked by art students that the aesthetic value of Wain's work became greater, and the drawings more interesting, in the early stages of his regression. Another clear example of such representational regression in a mental patient can be found in the *Cunningham Dax Collection: Selected Works of Psychiatric Art* by E. C. Dax (1998), where the artist/patient is listed under schizophrenia. We are informed he suicided not long after the last more stage-regressed drawing.

In contrast to stage regression in psychiatric pathology, recovery from mental disturbance should result in—and reveal—reconstitution of the four-stage hierarchy of representational capacity. An example of this is shown in the works of "Mr. Pauli" (Figure 9). As reported by R. M. Simon (1997), Pauli began painting in a psychiatric group; he subsequently left the group, was discharged from the hospital, and lived on his own. He apparently became progressively "more normal", as evidenced in the sequence of his works that were left at various times at Simon's door. The last picture Pauli brought to her is shown in Figure 9d, a robust representation of a Stage 4 drawing.

A student of the first author who was working in a

5 The artist's portraits are illustrated in Zaidel (2005, pp. 26–28). The paintings move from very schematic, even child-like, in Figure 2.1(a) to flat and cartoon-like in Figure 2.1(b) to real depth in Figure 2.1(g).

hospital observed a patient who showed stage recovery in her drawings, as shown in Figure 10 (a, b, c). The drawings were done while the patient was in a short-term psychiatric ward in New York City. The first day she was admitted she drew 10a; the next day 10b; and on the third day, shortly before being discharged, she drew 10c. Figure 11 (a, b, c) presents the drawings of another patient admitted to the same short-term psychiatric ward and shows, in contrast, systematic stage regression. The drawings were produced on the first, third, and fourth day after his admission (11a, b, and c, respectively); a day later he was transferred to a long-term psychiatric ward. These observations suggest that stage-level evaluations of a person's drawings may be useful for getting a quick measure of the degree of pathology.

Recent papers that provide some support from human regressed drawings for the Model's predicted stage changes in the images produced include the following: Annoni, J. M., Devuyst, G., Carota, A., Bruggimann, L., & Bogousslavsky, J. (2005). Changes in artistic style after minor posterior stroke. *Journal of Neurology, Neurosurgery & Psychiatry, 76*(6), 797-803; Bogousslavsky, J. (2005). Artistic creativity, style and brain disorders. *European Neurology, 54*,(2), 103-111; Chatterjee, A., Bromberger, B., Smith II, W. B., Sternschein, R., & Widick, P. (2011). Artistic production following brain damage: A study of three artists. *Leonardo, 44*(5), 405-410; Kleiner-Fisman, G., & Lang, A. E. (2004). Insights into brain function through the examination of art: the influence of neurodegenerative diseases. *Neuroreport, 15*(6), 933-937.

Discussion

Visual system location. There is a modest but relevant literature on the anatomical localization of processing of phosphenes and related visual images in humans. Chapanis, Uematsu, Konigsmark, and Walker (1973), and Brindley and Lewin (1968) report the sensations induced by stimulation of the visual cortex of a recently blinded woman. It was shown that stimulation using a simple cortical electrode usually led to the sensation of a single spot of light at a constant location in the visual field. It was also reported that simultaneous stimulation by several electrodes caused the patient to perceive predictable simple patterns. (These findings support our model and proposed mechanisms of Stages 1 and 2). Chapanis et al. (1973) studied three patients implanted with thalamic electrodes via the occipital lobe. Electrical stimulation of the electrodes led to the perception of phosphenes described as round, square, triangular, or rectangular. (This is evidence for Stage 2). Lance (1976) reported that Foerster (1931) had claimed that unformed visual hallucinations (such as flashes of light) originated in the retina or primary receptive area for vision in the occipital cortex (Brodmann's areas 17 and 18); he also reported that organized images were obtained by stimulation of area 19. Lance summarized reports by his patients who had parieto-occipital lesions and concluded that their perceptions consisted primarily of objects, people, and animals, and that those were presumably "the common building blocks of visual memory, a matrix for the channeling of visual memory rather than the visual memory itself" (p. 732). He stated that these images were more complex than the "flashes, zigzags and wholes of light and color obtained from the primary visual cortex" (p. 732). These reports provide evidence for Stages 1, 2, and 3 of visual processing, consistent with hierarchical mechanisms progressing from lower to higher levels. Finally, a review by ffytche and Howard (1999) summarized the hallucinations of 50 patients with degenerative ocular disease in which they reported that the patients' hallucinations were rather stereotypical, and that the visions were likely due to de-stimulatory, indirect neuropathological changes of the visual cortex rather than pathology of the eye, directly. The ocular diseases were senile macular degeneration (58%), glaucoma (18%), and a variety of other pathologies (24%). Given the different pathological etiologies of blindness and the absence of any focal cerebral pathology, one should not expect a simple connection between the type of hallucination and the CNS-dependent stages described by our model. Yet all of the reported images are representative of one of the four Stages of the model, although the effects (e.g., of movement, size change, etc.) appear to be unrelated. Reports of visual phenomena (see ffytche & Howard, 1999, p. 1250) included "fireworks exploding in vivid color" (Stage 1), "nets in sharp geometric shapes" and other patterns (Stage 2), multiple copies of objects, for example, rows of mugs, faces distorted, or cut-up like an early Picasso (Stage 3), and a number of naturalistic images (Stage 4).

Is this merely serendipitous, or do these perceptions support distinct CNS effects of differing visual activity? To propose an answer, we address where the model's stages *might* engage local network activities in the brain. Stage 1, we propose, takes place in the retina, the lateral geniculate nucleus (LGN), and the primary visual cortex (A17), and is probably completed at the color center found at V4 (Zeki, 1990). Hence this stage is presumed to reflect relatively low-level neuro-cortical events. It is well known that color, brightness, and spot- or point-shaped receptive fields are found in the retina and lateral geniculate nucleus (LGN), and that V4 is a kind of final-stage color center. We posit that these structures constitute the primary neurological substrates for Stage 1 processing. Studies by Grüsser, Grüsser-Cornehls, Kusel, and Przybyszewski (1989) seem to support this contention.

We believe that Stage 2 mostly engages the primary or initial areas of the visual cortex, where orientation, straight lines, and angles are detected—that is, V1–V3 and probably somewhat higher visual areas, and possibly also a final center, analogous to the Zeki color center, which organizes abstract geometric shapes.

Stage 3 processing is assumed to take place and be completed in as yet unidentified higher levels of the cortex, although various studies implicate the lateral-occipital complex (see below). More specifically, Stage 3 can be interpreted as engaging an object recognition area. This means that objects are first recognized in schematic, simplified form, and that this takes place after Stage 2 processing, and before Stage 4.

Research on object recognition supports the idea that the proposed Stage 3 engages higher, and perhaps multiple, cortical and extra-cortical networks—see, for example, Malach et al. (1995). In general, there is reliable evidence that there are two visual processing systems, one for recognizing forms/object ("what" is seen), and the other for locating the object in the visual space ("where" it is seen) (Ungerleider, Courtney, & Haxby, 1998). Object recognition is processed in the ventral visual network, probably involving the lateral-occipital complex (Haxby et al., 1999; Kanwisher, Woods, Iacoboni, & Mazziotta, 1997). Doniger, Silipo, Rabinowitz, Snodgrass, and Javitt (2001) used schematic representations (e.g., simple cartoon-like representations of an elephant), and noted that this type and level of recognition takes place in the lateral-occipital complex, secondary to early cortical visual processing (i.e., V1–V3) where we presume most of Stage 2 occurs.

It is important to note that in this model, the actual location for object recognition need not be specified, but only that the process involves hierarchical networked activations. There is an extensive body of research on object recognition that has used schematic or cartoon-like drawings of objects, which implicitly supports the presence of Stage 3. For example, the line drawings of Snodgrass and Vanderwart (1980) support this hypothesis. There is also evidence that the human visual system can recognize objects from partial information (Snodgrass & Feenan, 1990). This capacity, called "perceptual closure", implies that simple object schemas are present in the visual system and can be activated by incomplete (object) information. We hold that this strengthens our concept of Stage 3 processing.

Our model of Stage 3 and (possibly) Stage 4 processing, as noted, receives further support from studies that have shown object recognition and spatial vision to be subtended by separate cortical loci/networks. Presumably 3-D spatial representation and localization of an object occurs at Stage 4, after earlier schematic or simplified object recognition. (See Kohler, Kapur, Moscovitch, Winocur, Houle, 1995; Moscovitch, Kapur, Kohler, Houle, 1995 for discussion.) The present model, in its simplest form, implies that the perceptual construction at Stage 3 does not include the functional or associative meaning of an object. Presumably these properties are processed at higher levels of the networked hierarchy that are different from, and probably subsequent to, the perceptual construction of the object per se.

Recent papers that provide support for the Model's claim that in the case of hallucinations the hierarchical four stages or kinds of image involve the firing of specific visual receptors in the known visual system include: Baker, T. I. & Cowan, J. D. (2009). Spontaneous pattern formation and pinning in the primary visual cortex. *Journal of Physiology-Paris, 103*(1), 52-68; Billock, V. A., & Tsou, B. H. (2012). Elementary visual hallucinations and their relationships to neural-pattern forming mechanisms. *Psychological Bulletin 138*(4), 744-774; Bressloff, P.C., Cowan, J. D., Golubitsky, M. Thomas, P. J. & Wiener, M. C. (2002). What geometric visual hallucinations tell us about the visual cortex? *Neural Computation, 14*(3), 473- 491; Poggel, D. A., Muller-Oehring, E. M., Gothe, J., Kenkel, S. , Kasten, E. & Sabel, B. A. (2007). Visual hallucinations during spontaneous and trained-induced visual field recovery. *Neuropsychologia, 45*, 2598-2607.

Our input-processing model predicts that mental pathology—schizophrenia, for example, or neurological deterioration (e.g., Alzheimer's disease)—could insult and affect the input processing at one or more stages, not just the systems that are involved in output or drawing. That is, if the drawing ability of a patient suffering from mental pathology regresses to Stage 3 or 2, then this deterioration in output might be accompanied by and reflect deterioration of the related perceptual processing. Support for this interpretation is provided by Doniger et al. (2001) who report that schizophrenics have object recognition deficits that are likely due to impaired sensory/perceptual processing.

Some four decades ago, Klüver (1966, as cited by ffytche and Howard, 1999, p. 1255) observed commonalities in abnormal visual experience that suggested "some fundamental mechanisms involving various levels of the nervous system." The present model, while focusing on artistic perception and output (i.e., drawing), reinforces and extends these findings.

Parallel and serial processing. It is well established that parallel processing underlies much visual perception. Certainly, within a stage (of our model), parallel processing can, and (we presume) commonly does occur. For example, if we consider Stage 1 to be primarily subtended at retinal and LGN levels, then the parallel processing of these substrates—as contributory to Stage 1 perception—is well known. The actual relationships of neural networks involved in higher levels of the model, as far as we are aware, remain unknown, although the connection of Stages 1 and 2 can be considered a function of the visual radiations engaging (the highest) Level 1 processing onto Stage 2.

It is important to note, however, that serial processing also operates within this model: The four qualitative stages of our model are explicitly predicted to occur in a hierarchical sequence—that is, the gross structure of the model involves hierarchically qualitative stages that are, at the macro level, serial. The qualitative stages in the model are consistent with the known fact that cortical areas have an identifiable hierarchy based on laminar patterns of inputs and outputs. There is strong evidence for certain types of serial processing in the cortex—see, for example, Doeringer and Hogan (1998); Hubel and Wiesel (1965, 1977); Inui, Wang, Tamura, Kaneoke, and Kakigi (2004); and Pons, Garraghty, Friedman, and Mishkin (1987). Nevertheless, as noted, the model is assumed to predominantly involve parallel processing, especially within a given stage. Still, it is reasonable to presume that parallel and serial processing occur synergistically both within and between levels of the hierarchy. This is consistent with hierarchical cognitive function as proposed by Jackendoff (1987) and extended by Prinz (2000).

Bottom-up and top-down processing networks. As presented, the model could be seen as a bottom-up processing model; however, we accept the recently proposed interpretations that cortical processing commonly involves bi-directional networked hierarchies, such that prominent bottom-up and top-down effects are reciprocal (Bar, 2003; Hawkins, 2004; Prinz, 2000). The present model allows this bi-directionality within and between stages. For example, at Stage 2, ascending and descending networks are presumed to be involved in the perception/construction (and production) of lines and geometrical patterns initiated by the stimulus; the descending projections may involve maintenance of the accuracy of stimulus input so as to strengthen, focus, and perhaps contextualize it to other dimensions of cognition and/or emotion. This is consistent with the cited models and would reflect complex dynamical systems activation and integration in the CNS.

The model and primitive art. Animals do not draw, unless artificially encouraged to do so by humans—and even then they show no reliable evidence for drawing recognizable objects. Therefore, we (like others) assume that making designs and drawings constitute distinctly human activity. It is also likely that drawing is closely connected to human language. Indeed, the existence of designs, much less drawings, have been commonly used as evidence for "identifying" the first humans—that is, the first primates capable of human consciousness and capable of symbolic thought and expression. There is much debate over when and where this occurred. Some have argued for a relatively recent date of around 32,000 BCE (Pfeifer, 1982), and others for around 75,000 BCE (Hogan, 2003). A few claim that very simple marks are examples of even earlier human art. The very earliest claims are for "cupules" (Bednarik, 1993), which are small hemispherical indentations pounded into flat, sloping, or vertical rock surfaces. Cupules are very analogous to the present model's understanding of the simplest and earliest element, the dot. However, when cupules are found without other more complex markings, the claim that they represent early art seems to stretch the concept of art to a breaking point. Regardless, for present purposes, it is a common observation that in the case of primitive art, very simple elements appear first, then geometric patterns, then more complex designs, and finally stick drawings and schematic objects. More complex realism comes still later, if at all. (See also Zaidel, 2005).

In concluding we summarize: The present model is a four-stage hierarchical description both of how an image is processed or constructed to visual completion and also of how it is produced when the image is drawn. Supporting evidence is drawn from the following: more than a century of published reports of visual hallucinations; the extensive literature on the development of children's drawings; and artistic regression in persons suffering from mental or medical pathology. In addition, much recent research in cognitive neuroscience has been cited to connect the model, at least in a general way, to brain functions. The model may also bear on historical development or changes in art, such as interpretations of the origin of art in early human societies.

Finally, this paper by focusing on the relevance of a patient's art interprets the patient as a whole person, not just a collection of parts, thus emphasizing medicine as an integration of both the sciences and the humanities.

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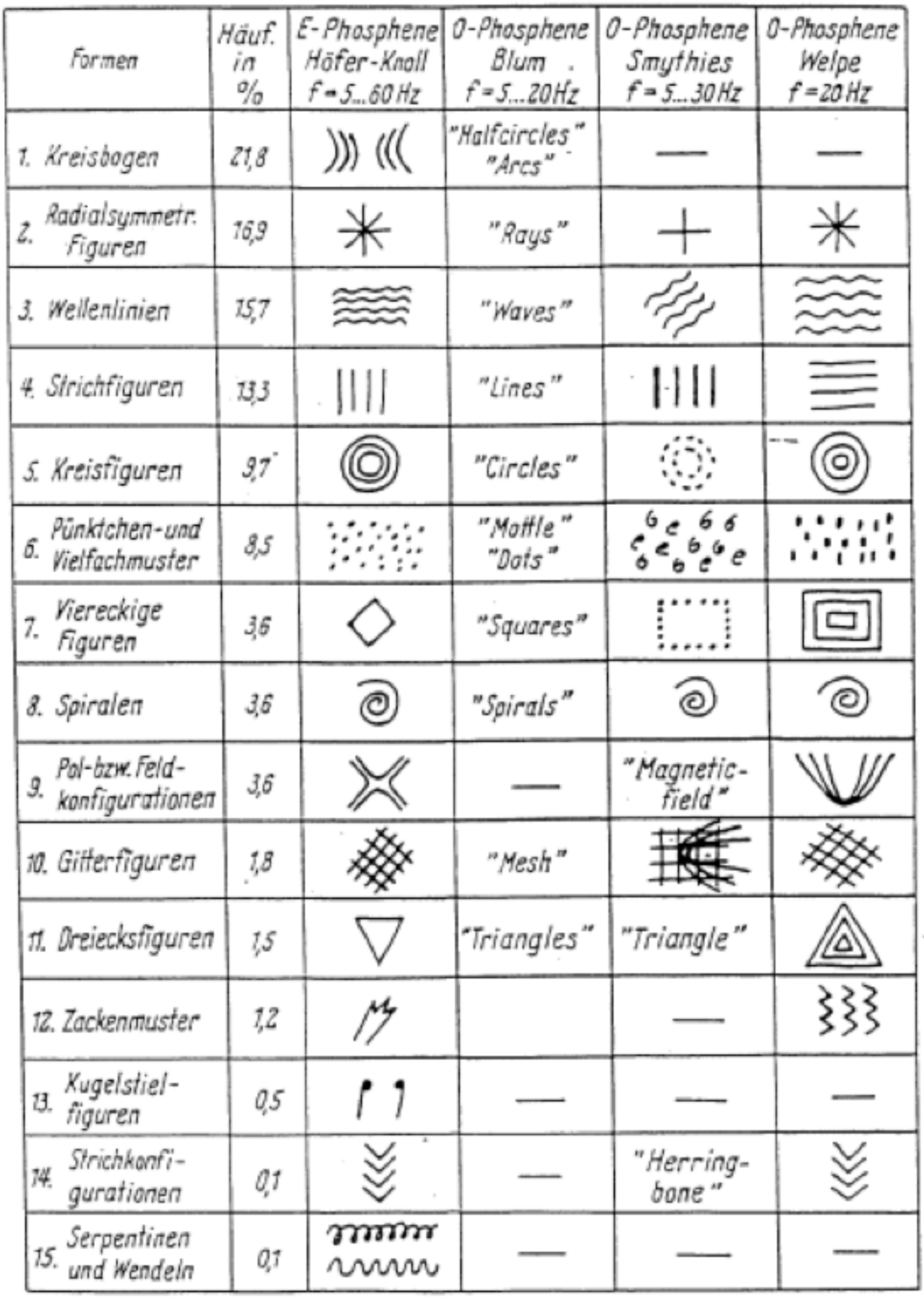
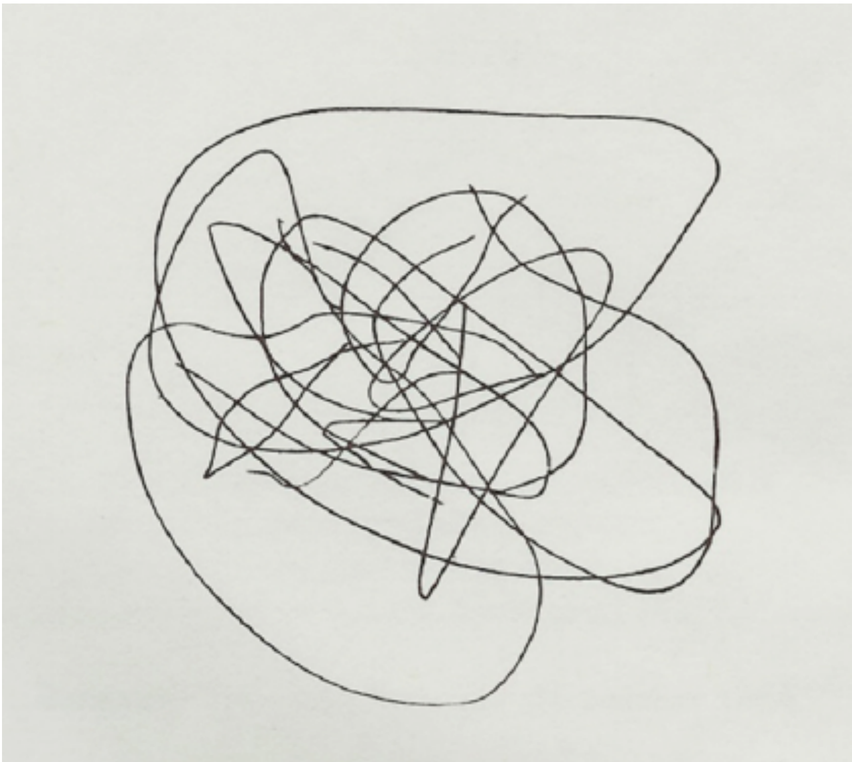


Formen	Häuf. in %	E-Phosphene Höfer-Knoll f = 5...60 Hz	O-Phosphene Blum f = 5...20 Hz	O-Phosphene Smythies f = 5...30 Hz	O-Phosphene Welpe f = 20 Hz
1. Kreisbogen	21,8		"Halfcircles" "Arcs"	—	—
2. Radialsymmetr. Figuren	16,9		"Rays"		
3. Wellenlinien	15,7		"Waves"		
4. Strichfiguren	13,3		"Lines"		
5. Kreisfiguren	9,7		"Circles"		
6. Pünktchen- und Vielfachmuster	8,5		"Mottle" "Dots"		
7. Viereckige Figuren	3,6		"Squares"		
8. Spiralen	3,6		"Spirals"		
9. Pol- bzw. Feld-konfigurationen	3,6		—	"Magnetic-field"	
10. Gitterfiguren	1,8		"Mesh"		
11. Dreiecksfiguren	1,5		"Triangles"	"Triangle"	
12. Zackenmuster	1,2			—	
13. Kugelstiel-figuren	0,5		—	—	—
14. Strichkonfi-gurationen	0,1		—	"Herring-bone"	
15. Serpentinen und Wendeln	0,1		—	—	—

Figure 1. Various types of phosphenes ("Munich taxonomy"): Stage 1 images (sensory: amorphous, #6), and the rest Stage 2 (perceptual: geometric). From "Vergleich von Anregungsbedingungen, For-Klassen und Bewegungsgarten optischer und elektrischer Phosphene" [Comparison of excitation conditions, shapes, and movement of optic and electric phosphenes], by M. Knoll and E. Welpe, 1968, *Elektro Medizin. Biomedizin und Technik, 13,* 128–134.

a.



b.

Figure 2. Children's scribble drawings: (a) scribbles in curved, diagonal lines, by a boy, aged 16 months and (b) round scribbles by a boy, aged 20 months. From Children's Human Figure Drawings (Vol. 2) by K. V. Mortensen, 1984, p. 444. Copyright 1984 by Dansk Psykologisk Forlag.

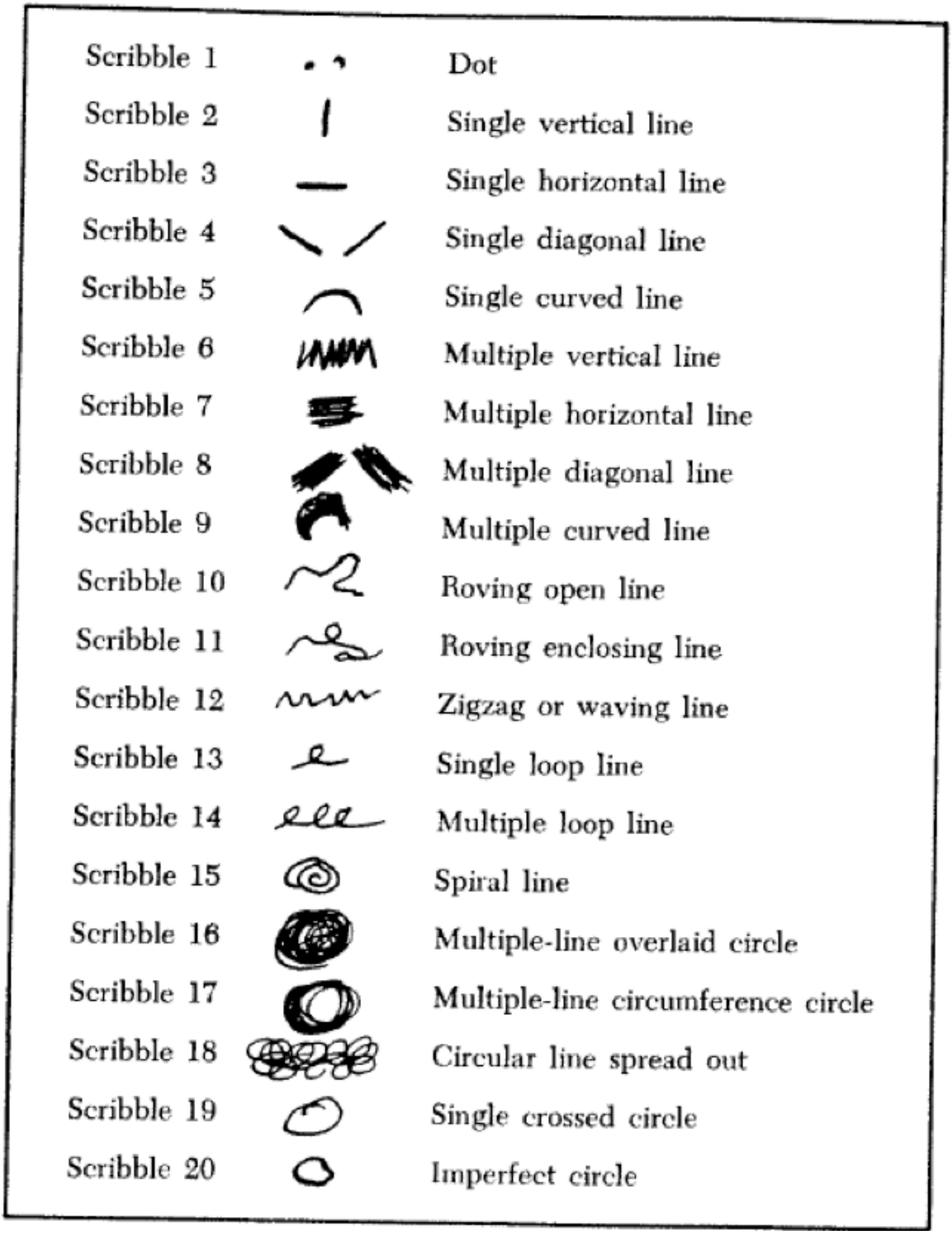
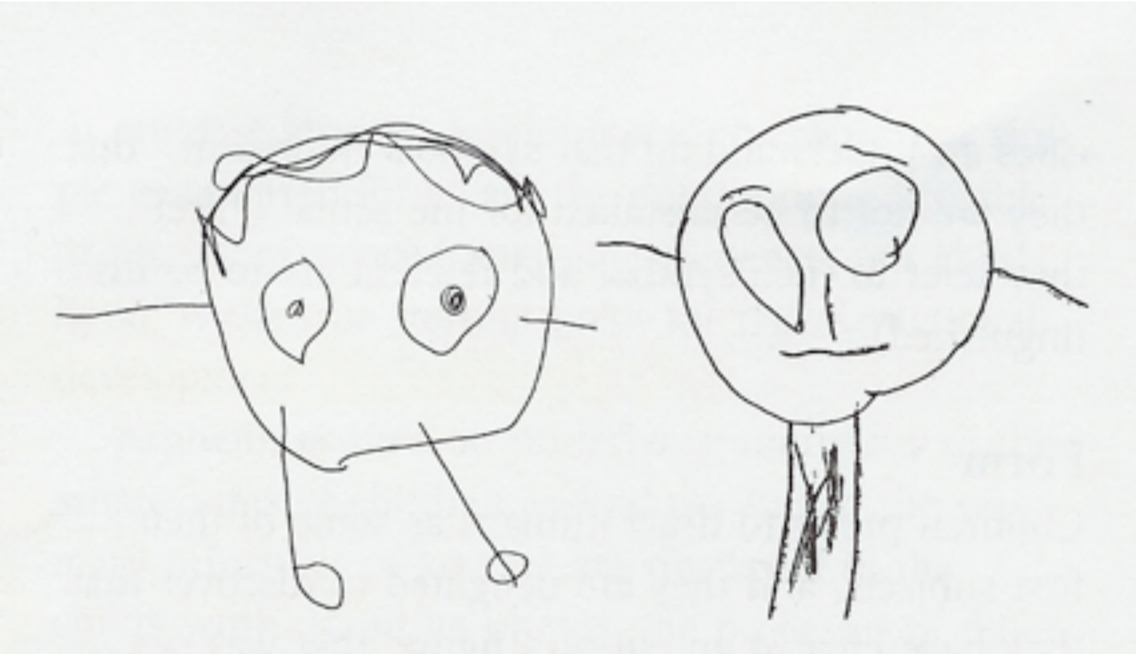


Figure 3. Children's drawings: the basic scribbles. Except for the dot and roving lines (Stage 1), all these are Stage 2 images (perceptual: geometric). From Analyzing Children's Art by R Kellogg, 1970. Copyright 1970 by National Press Books, Palo Alto, Ca.



a.

b.

Figure 4. Children's drawings, human figure: (a) tadpole figures by boys aged 3 ½ and 4 ½ years and (b) human-figure drawing by a 6-year-old girl. From Child Art in Context: A Cultural and Comparative Perspective by C. Golomb, 2002, pp. 20, 30. Copyright 2002 by the American Psychological Association.

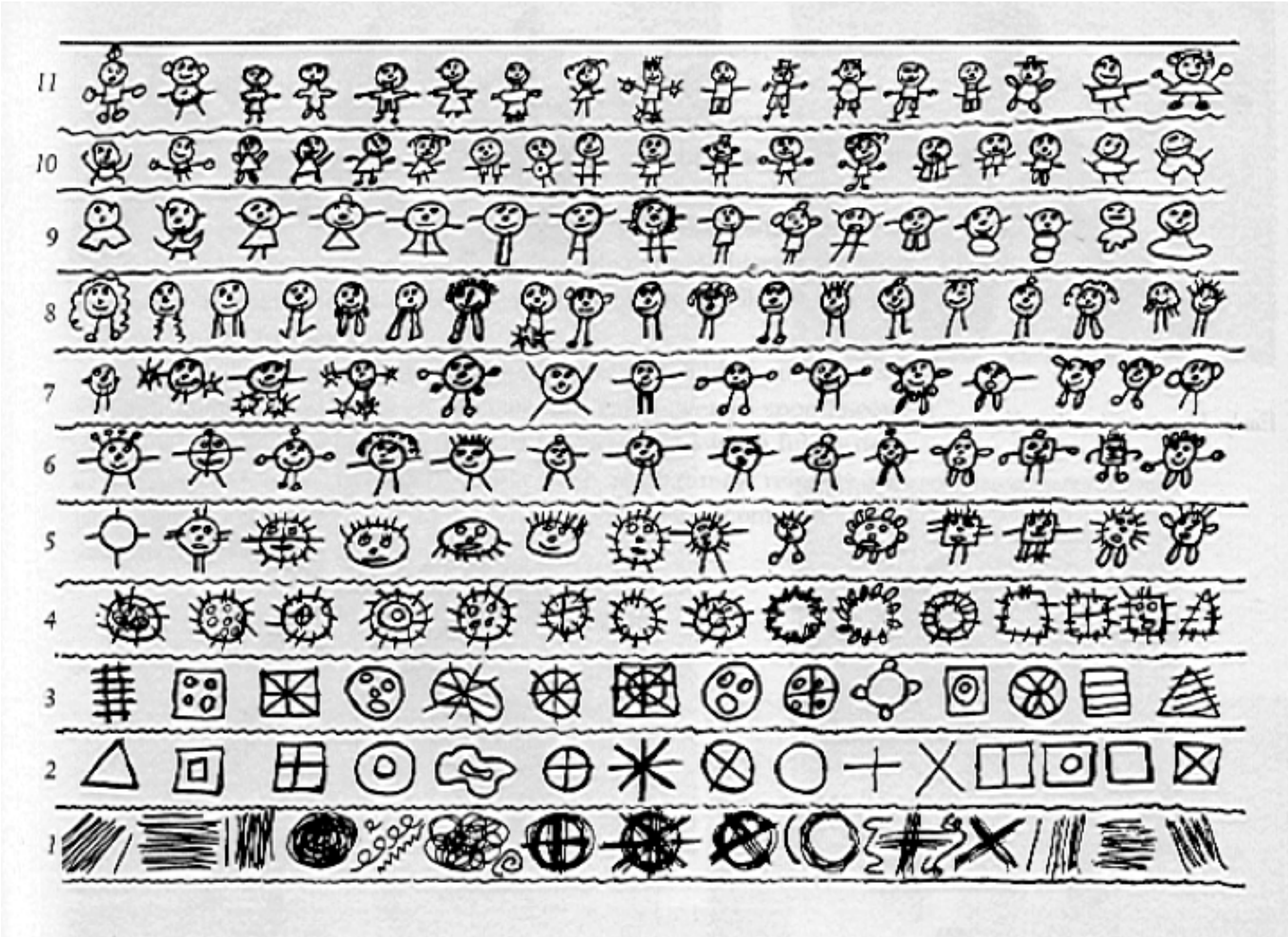
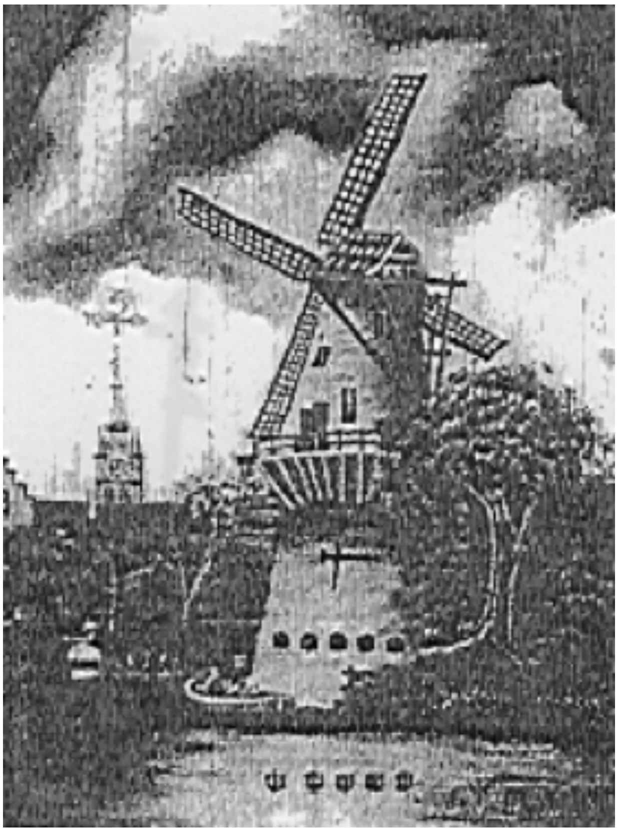
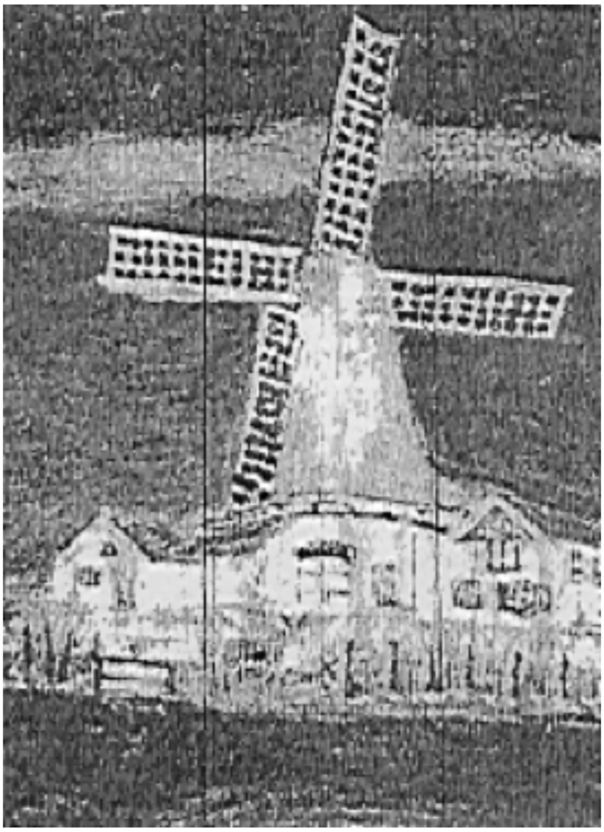


Figure 5. Stages of children's drawings: Stage 1 (sensory-amorphous: scribble); Stage 2 (perceptual: geometric); Stage 3 (cognitive: schematic). From Analyzing Children's Art by R Kellogg, 1970. Copyright 1970 by National Press Books, Palo Alto, Ca.

a. 

b. 

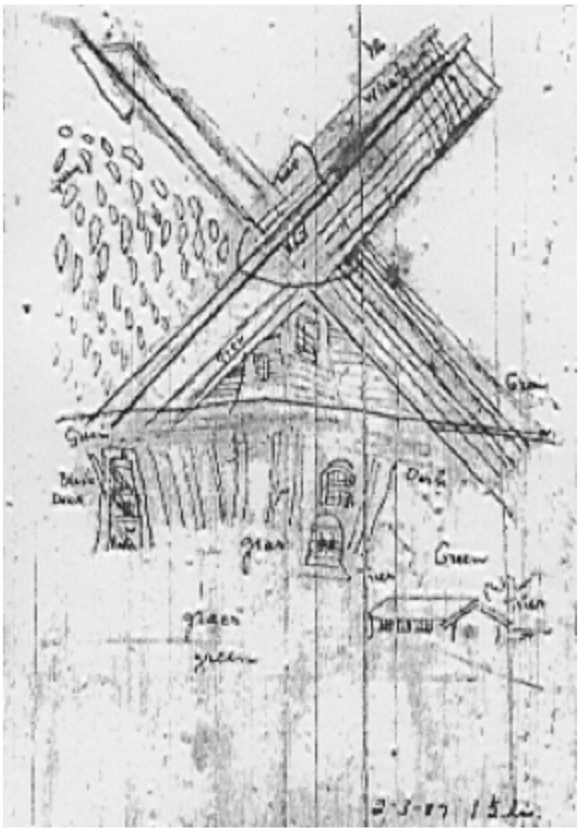
c. 

Figure 6. Regression in an Alzheimer's patient who was an artist: The first image (a) is a mill painted near time of onset of symptoms suggestive of Alzheimer's disease; the second (b) was painted seven years after onset of Alzheimer's disease, when language and memory abnormalities were well established; and the third (c) is a sketch of the mill completed nine years after onset of the disease, where loss of perspective, perseveration, and intrusion of irrelevant details are clearly evident. Figure 6a is a Stage 4 image (comprehensive: realistic); by 6c the image is a schematic Stage 3 with some geometric Stage 2. From "Probable Alzheimer's Disease in an Artist" by J. L. Cummings and J. M. Zarit, 1987, The Journal of the American Medical Association, 258, pp. 2731–2734. Copyright 1987 by the American Medical Association.

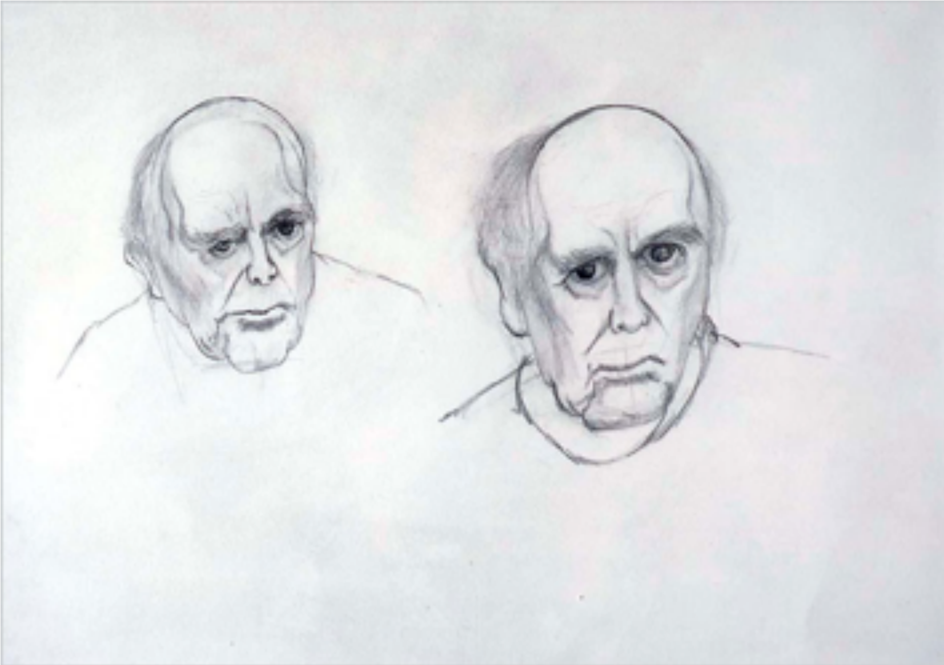
a. 

b. 

c. 

Figure 7. Images illustrating regression in an Alzheimer's patient: the image in (a) is Stage 3 (cognitive: schematic), which by (c) is showing strong Stage 2 components (geometric). From "The Graphic Representation of Regression in an Alzheimer's Disease Patient," by J. Wald, 1984, The Arts in Psychotherapy, 11, pp. 165–175. Copyright 1984 by Elsevier Ltd.

a. 1996



b. 1997

c. 1999

Figure 8. Regression through the model's stages in the art of William Utermohlen. Galerie Beckel Odille Boïcos, Paris, France.

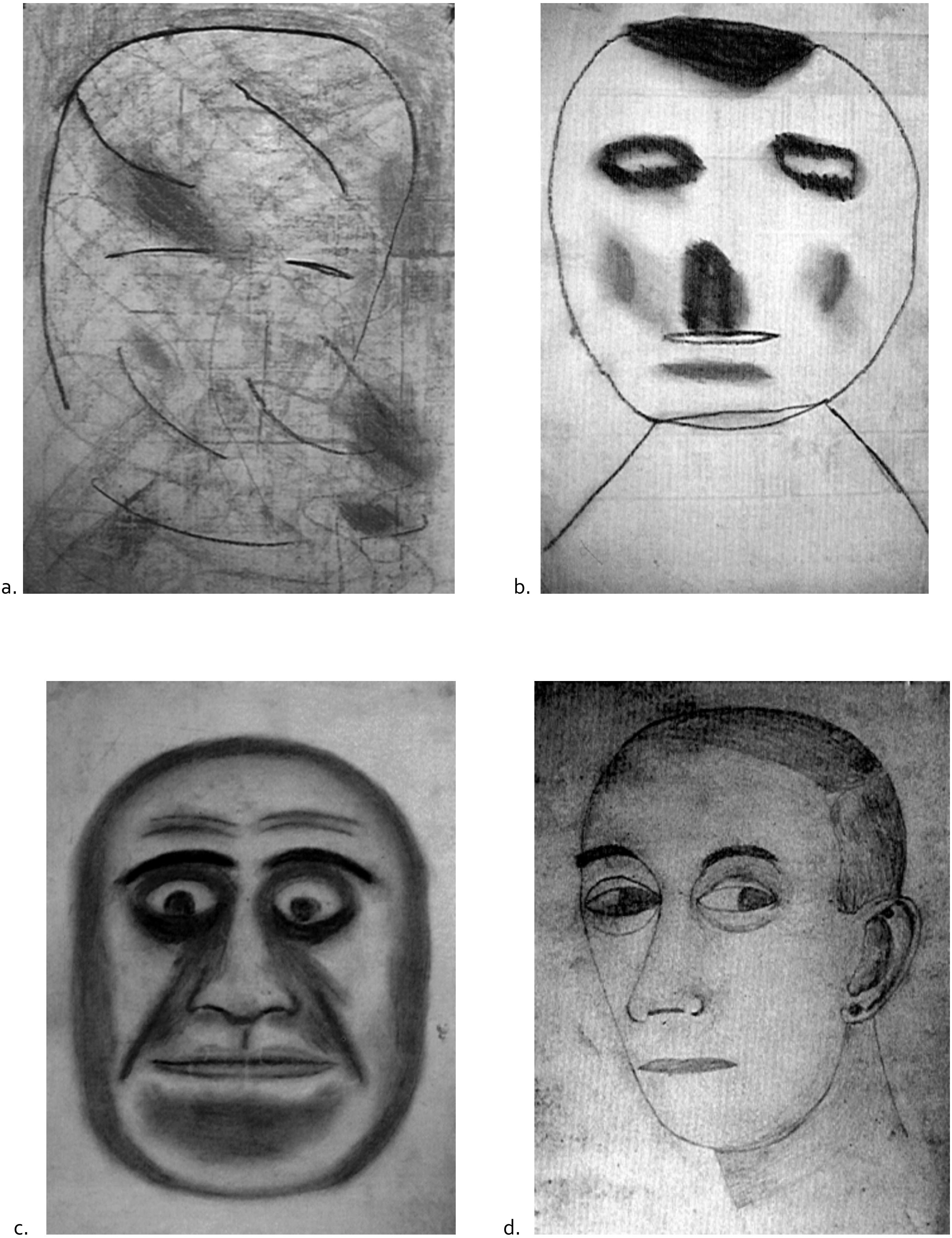


Figure 9. An example of psychiatric recovery (progression) in drawing levels: drawings in chronological order by "Mr. Pauli," from (a), mostly Stage 1 to (d), with strong Stage 4 characteristics. From Symbolic Images in Art as Therapy by R. M. Simon, 1997. Copyright 1997 by Routledge.

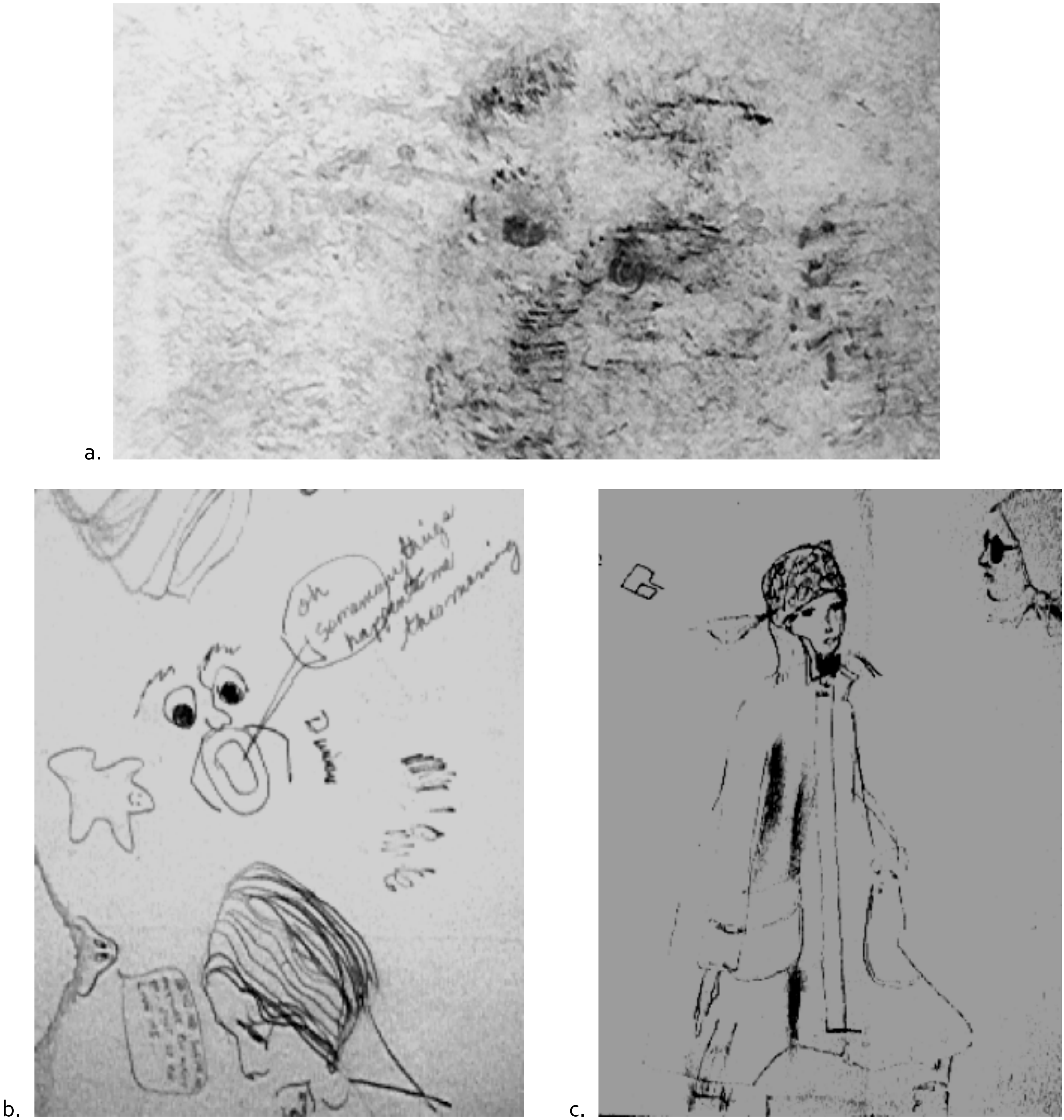
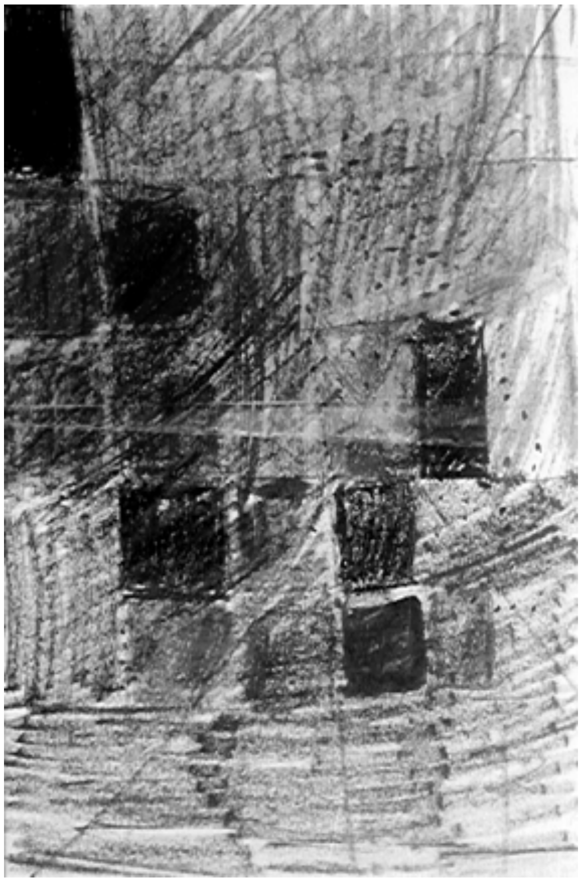


Figure 10. An example of psychiatric recovery (progression) in drawing levels. These drawings were done by a patient in a short-term psychiatric ward in New York City: the first (a) was drawn on the first day, when the patient was admitted, and is mostly Stage 1, with some Stage 2 and 3; the second (b), drawn on the second day, is primarily Stage 3; and the third (c), primarily Stage 4, was drawn shortly before her discharge from hospital on the third day.

a. 

b. 

c. 

Figure 11. An example of a psychiatric regression in drawing levels by a patient admitted to the same short-term psychiatric ward (see Figure 10) in New York City before being discharged to a long-term psychiatric ward. The drawings were produced on the first, third, and fourth day after his admission: (a) mostly Stage 3, with some Stage 2; (b) Stage 2 and Stage 1; and (c) mostly Stage 1, some Stage 2.