CHAPTER 23

PICTORIAL ART BEYOND SIGHT: REVEALING THE MIND OF A BLIND PAINTER

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Painting is a blind man's profession, as blind people have a clearer vision of reality

Pablo Picasso

I wish I had been born blind, because it would have enhanced my artistic perception of the world

Claude Monet

The average blind person knows more about what it means to be sighted than the average sighted person knows about what it means to be blind

Georgina Kleege, 'Blindness and Visual Culture: An Eyewitness Account', 2005

Introduction

Artistic expression is a complex behaviour that engages many aspects of perception, cognition, and emotion (Zeki 2001). Painting and, in particular, drawing, represents a form of visual communication associated with the ability to construct, manipulate, and ultimately translate the contents of one's own mental representations (Livingstone 1988). Inherent to this process is the engagement of mental imagery—the role of which has been well established in visuospatial reasoning and creative thought (Kosslyn et al. 2001). Current evidence suggests that in sighted individuals, mental representations are pictorial in nature rather than symbolic or verbal (Kosslyn et al. 2001; Kosslyn 2005; Slotnick et al. 2005), and that mental imagery draws on much of the same neural machinery as visual perception (Mitchison 1996; Kosslyn 2001).

Conventional wisdom assumes that visual mental imagery is largely dependent on recollections of prior visual experience. If so, any impairment in the development, or function, of the visual system should critically modify one's ability to create and manipulate visual mental representations. Thus, the lack of any prior visual experience would likely impede upon a person's ability to create the visual mental constructs required for artistic expression. Is it possible to generate mental pictures via alternate sensory modalities in the absence of any prior visual experience? If so, what are the neural substrates that support such a process? This is what we discuss here in the framework of understanding vision, brain reorganization in blindness, and the interactions between brain research and art.

Brain plasticity and brain reorganization

The brain, comprised of billions of highly specialized cells, is intricately arranged into precise patterns and connections. Initially, these networks are laid out during development and controlled by a variety of genetic factors. Neurons, given their sophisticated and complex degree of specialization, are likely highly stable and resistant to change. However, what is now becoming increasingly clear is that neural networks and the connections between neurons are highly dynamic and constantly changing in response to environmental input and experience. The nervous system's ability to change, or 'neuroplasticity,' is an ongoing, lifelong process and is an intrinsic property of the brain (Pascual-Leone et al. 2005).

Alcmaeon of Croton, probably the first person to suggest that the mind is located in the brain and not the heart, also suggested that the optic nerves are light-bearing paths to the brain. His revolutionary ideas, formulated about 2500 years ago, were ignored by Egyptian and Greek scholars alike (most notably by Aristotle). On the basis of the vast amount of anatomical and electrophysiological studies, we now have a picture of a highly diverse and hierarchically structured system (Hubel and Wiesel 1963, 1965; Zeki 1978; Felleman and Van Essen 1991). This hierarchical organization originates in the photoreceptors of the eye, to the optic nerve via the thalamus, to primary visual cortex (visual area V1), and beyond to an array of higher-order visual areas. These visual areas, located in the occipital lobe (one of the four lobes of the cortex) in the back of the brain, cover a large portion of the brain. But what is the fate of these areas in an individual who becomes blind, or even, in an individual born without sight? Studying people who are peripherally blind (for example, from disease or damage to the eye) provides a unique opportunity to investigate this question and in particular, uncover the neuroplastic changes that follow blindness and its associated behavioural consequences.

Blind individuals have to make striking adjustments in order to adapt within a world that relies heavily on vision. Remarkably, they learn to extract relevant information about their surroundings using their remaining senses. When assessing behavioural tasks involving touch, hearing, and memory, there is ample evidence that blind individuals perform on par, or in some cases better, than those with sight (Hollins and Kelley 1988; Rauschecker 1995; Lessard et al. 1998; Roder et al. 1999; Van Boven et al. 2000; Amedi et al. 2003; Gougoux et al. 2004; Collignon et al. 2008;). This suggests that changes and adaptations take place in the brain and in turn, may be responsible for these compensatory behaviours. Accumulating evidence now points to the notion that these neuroplastic changes occur within the part of the brain once dedicated to the process of vision itself. Over the last decade, key studies have shown that, in the blind, the occipital visual cortex is engaged in processing non-visual sensory information such as Braille reading and tactile object recognition (Sadato et al. 1996, 1998, 2004; Buchel et al. 1998; Burton et al. 2002, 2006; Amedi et al. 2003) while deactivating the visual cortex of early blind by transcranial magnetic stimulation (TMS) abolishes Braille reading capacity (Cohen et al. 1997; Kupers et al. 2007) and TMS of the occipital cortex induces tactile sensations in the blind Braille readers (Kupers et al. 2006; Ptito et al. 2008). The occipital cortex is also engaged in auditory information processing, including particularly sound source localization (Kujala et al. 1995, 2005; Gougoux et al. 2004, 2005) and even cognitive linguistic tasks such as verb generation and verbal memory (Roder et al. 2002; Amedi et al. 2003, 2004; Ofan and Zohary 2007).

Given that the blind use parts of the occipital cortex that sighted use for visual processing, to process other sensory modalities, many interesting questions arise: is the 'visual' brain of the blind the same as that of the sighted? Can the occipital 'visual' cortex always process other sensory modalities, or is it fundamentally different in the blind and the sighted? Do the blind mentally imagine the world the same way as the sighted, or do other sensations cause a form of mental imagery that is inherently different? What is the nature of the mental representations within the blind brain? How could one gain insight into this question? Our brains are fundamentally creative, so how does the lack of prior visual experience influence this process? As we will discuss here, one way to explore these questions is through the expression of art.

Art, mental imagery, and the brain

Art can be considered as an externalization of the inner workings of the brain (Zeki 2001). Inherent to an artistic ability is the engagement of mental imagery—that is, the ability to create a mental image with the 'mind's eye'. The process of mental imagery draws upon much of the same neural machinery (namely visual cortical areas) as visual perception itself (but see Amedi et al. 2005 for a complementary view). As mentioned earlier and taken to the extreme, would the lack of visual experience impede upon a person's ability to create visual mental constructs? From a behavioural level, we know that this is not entirely true.

Research using sensory substitution devices (Bach-y-Rita et al. 1969; Bach-y-Rita and Kercel 2003) provides an opportunity to further test these questions, and shows that blind individuals are able to construct an image perceived by an intact modality (e.g. tactile (Ptito et al. 2005) or auditory (Arno et al. 2001; Renier et al. 2004, 2005; Amedi et al. 2007)) by 'translating' information originated by the substituted modality (vision, via a camera instead of the eyes). Whether this process is performed by cross-modal changes (in other words, the recruitment of brain areas normally devoted to processing information from one sensory modality to process information coming from another modality) or mental imagery is a source of a wider debate (for extensive discussion see Poirier et al. 2007). Evidence also suggests that congenitally blind individuals are able to create mental sensory constructs and manipulate them (e.g. mental rotation or mental maze navigation) at performance levels equal to that of the sighted (Heller and Ballesteros 2006), to construct and understand tactile drawings (Kennedy 1983; D'Angiulli et al. 1998; Kennedy and Merkas 2000; Kennedy and Igor 2003; Kennedy and Juricevic 2006a,b), and according to Bertolo (2005), they are able to construct and make a drawing of one of their dream scenes. Next, we present a summary of recent results (Amedi et al. 2008), of a unique individual, E.A., that serves to discuss and further shed light on the questions we raised so far.

E.A. is a unique case of a blind painter

Subject E.A. is a profoundly blind painter who lost his vision at a very young age. Like other blind individuals, E.A. can capture the external world by touch. However, thanks to his extraordinary drawing ability, he can reveal the nature of his internal representation of objects captured by touch in a manner that is unequivocally understandable by a sighted person. Thus, by revealing his drawing to us, he is in a sense revealing the internal representations of his brain (for a nice collection of his paintings and drawing visit: http://www.armagan.com/paintings.asp). Furthermore, it appears that this representation matches that of what a sighted person would create despite his lack of prior visual experience.

In a recent study (Amedi et al. 2008), we concentrated on E.A.'s skill of drawing novel objects explored by touch and used functional neuroimaging (specifically, functional magnetic neuroimaging, or fMRI) to investigate the relationship between neural activity within the brain and specific mental functions. fMRI is a powerful tool that has long been used to measure certain aspects of brain function. In short, fMRI measures changes in the concentration of blood oxygen levels near a neural event and through a carefully designed experiment, allows one to identify the regions in the brain that are associated with a particular task or function (Logothetis and Wandell 2004; Friston 2005).

At the time of study, E.A. was a 51-year-old, right-handed male. A detailed neuro-ophthalmologic examination, including electrodiagnostic testing, confirmed his profound blindness. One of his eyes had never developed and the other showed massive corneal scaring, a dense cataract, and retinal damage consistent with early-onset blindness. Examination of previous medical records revealed that E.A. has never had normal vision and was profoundly blind by the age of five.

E.A. has described himself as a self-taught artist and is Braille illiterate. Growing up, he felt socially isolated because of his blindness and would often spend hours alone drawing in the sand and exploring the relief patterns of the figures he had drawn. At the age of six, he engaged seriously in art and painting. Without any formal instruction or schooling, E.A. started to paint using the tips of his fingers employing fast drying acrylics and water-colours as well as oils. He also learned to draw with a pencil and paper using a specially designed rubberized writing tablet (a Sewell raised line drawing kit) that allows him to generate relief images that he can subsequently detect and explore tactilely.

The themes of his paintings vary, and include objects that both can and cannot be tactilely examined (such as fruit and clouds, respectively). His scenes utilize a vibrant palette of colour, often containing shadows, depth cues, and perspective akin to that employed by sighted artists (see Fig. 23.1). His use of colour has obviously been guided by instruction from sighted individuals who have informed him about typical colour associations (for example, water is blue, trees are green, and the roofs of houses are often red). Other aspects of his painting are likely similarly influenced by information received from sighted observers (e.g. the painting of clouds or mountains). However, his ability to explore a novel object, rapidly draw it in exquisite detail, and from various vantage points, appears to be a skill he has developed without constant input or feedback from sighted observers (see Fig. 23.1).

Results from neuroimaging

We designed a study aimed at uncovering the neural activation patterns associated with subject E.A.'s drawing ability (Amedi et al. 2008). Using fMRI, we scanned subject E.A. under six different conditions: (1) while he explored and recognized an object

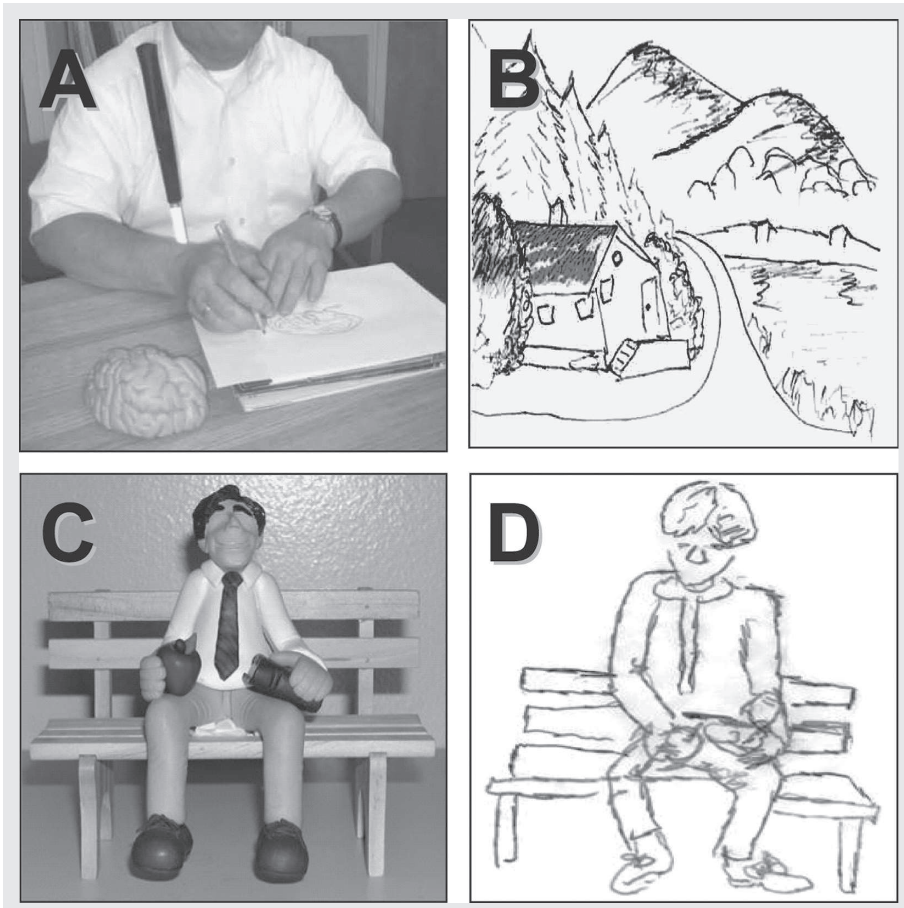

Fig. 23.1 Examples of E.A.'s drawing abilities. A) E.A. drawing a novel object (a model of a human brain) using a pencil and paper and a specially designed rubberized writing tablet (Sewell raised line drawing kit). This technique allows him to generate relief images that he can subsequently detect and explore tactilely. B) The themes of his drawings and paintings vary and include both tactile and non-tactile subjects. The drawing shows a landscape scene and illustrates how he applies colours to his paintings. His paintings often contain vibrant colour, and he uses shading, depth cues, and perspective akin to that employed by sighted artists. C) Example of a complex and novel object which E.A. had never encountered. Once E.A. explored the object by touch for a few minutes, he was able to render a very accurate drawing of the object D).

Adapted from Amedi et al. (2008).

including its tactile features through palpation; (2) while he drew the object he just tactilely explored; (3) while he mentally imagined the same object; and (4) while he retrieved the names of objects from a list previously memorized (verbal memory test). As control conditions, we also scanned E.A. while he (5) scribbled a 'nonsense' figure instead of an actual drawing and (6) moved his hands in space as if he were exploring an object.

In order to reveal the brain activity associated with E.A.'s drawing skill, we subtracted the activity we found while E.A. scribbled from that measured when he actually drew an object. In this way, we could better isolate the brain activation specifically associated with his drawing skill. We found clear activation in a variety of areas in the brain including prefrontal and parietal areas (see Fig. 23.2). Of particular interest was the activation seen within the occipital cortex, that is, the part of the brain that is normally activated when sighted individuals view a visual scene. Thus, when E.A. draws actual objects (even subtracting the activity associated with the sensory and motor acts associated with drawing itself), the part of his brain that is normally associated with seeing is activated even though he never saw (and has never seen) the actual objects he draws.

As a further analysis, we also compared activation patterns for the different control conditions. This included E.A. exploring objects tactilely, imagining the pictures he drew, and recalling the names of the objects he drew. Consistent with previous studies by our group and others (Ishai and Sagi 1995; Ishai et al. 2000a,b; O'Craven and Kanwisher 2000; Kosslyn et al. 2001; Mechelli et al. 2004; Amedi et al. 2005), we found activation in a variety of brain areas in each of these tasks. What was consistent (and contrary to what we found when E.A. drew) was the fact that early visual cortical areas were significantly less activated in all of these control conditions (Fig. 23.3). To further test this directly, we also performed a direct comparison between drawing objects and the tactile objects condition: we subtracted the activity we found while E.A. tactually explored objects from that measured when he drew an object (see Fig. 23.3A). We again found greater and selective activation of the occipital cortex during the drawing condition. Specifically we found the largest magnitude for drawing in the calcarine sulcus, corresponding to primary visual cortex of sighted (Fig. 23.3B). This suggests that the visual cortex is engaged in the drawing task and that the activation is not a manifestation of basic or high-level object related tactile processing.

Discussion and conclusions

Subject E.A. is a unique example of an early blind individual able to represent and communicate the internal representation of objects in his mind through his drawings. We used functional neuroimaging to investigate what brain areas were involved with E.A.'s drawing skill. We also analysed different components of E.A.'s drawing

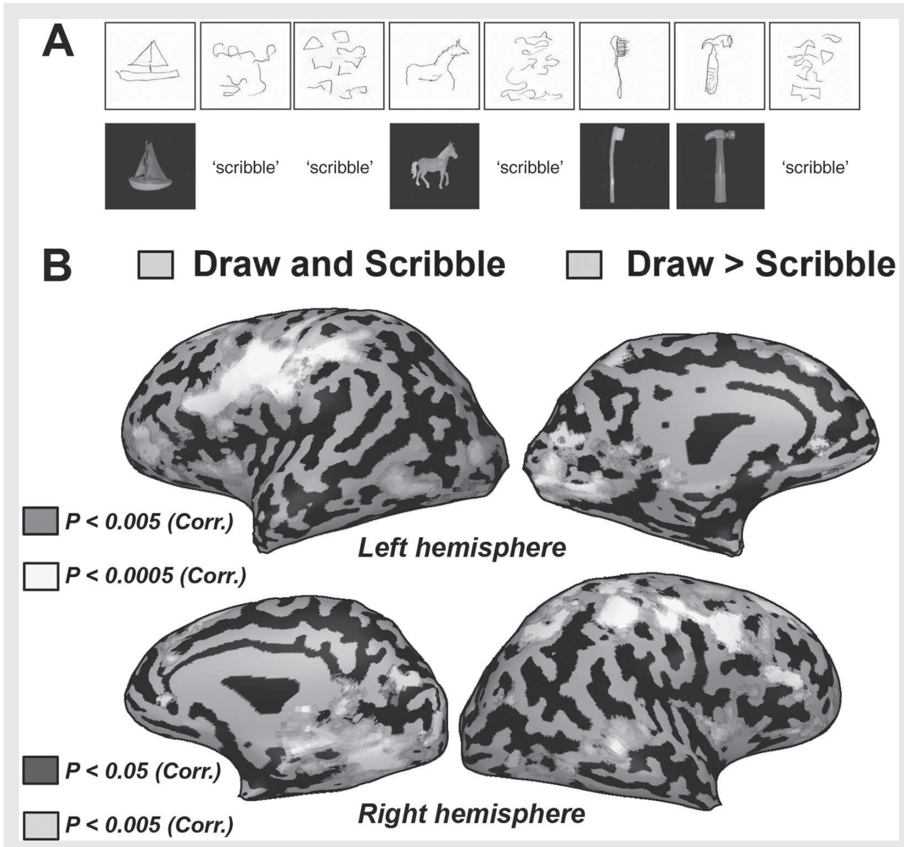

Fig. 23.2 (See Colour plate) Neuroimaging data of subject EA for drawing and scribbling objects. A) Example of behavioural data collected from a scanning run. Subject E.A.'s sketches (above) are shown compared to the object tactilely explored or in response to the control scribble condition (below). B) Activation patterns associated with the contrast of drawing versus scribbling presented on a full inflated cortical reconstruction of E.A.'s brain (lateral and medial views). Most striking is the activation seen in the occipital areas localized around the calcarine sulcus (identified by cyan arrows). The calcarine sulcus anatomically corresponds to early visual areas (V1 and V2) in normally sighted individuals. In EA, these areas are active for drawing.

Adapted from Amedi et al. (2008).

ability including the tactile perception of an object, verbal memory of object names, sensory–motor control, mental imagery of objects explored by touch, and scribbling. Thus, we were able to isolate each part of the perceptual and cognitive process involved. When E.A.'s drawing activity was compared to nonsensical scribbling, strong activation implicating a specific network of cortical brain areas was found. This network

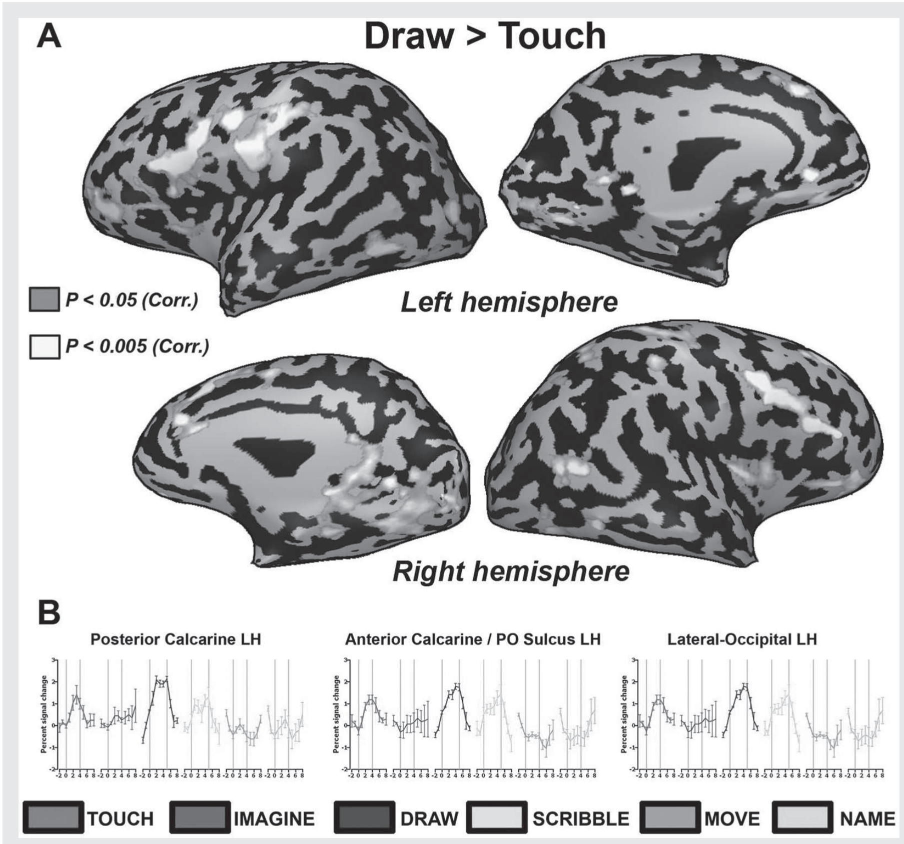

Fig. 23.3 (See Colour plate) Neuroimaging data of subject E.A. for a direct comparison of drawing versus tactilely exploring objects. A) The contrast of drawing versus touching objects is presented on a full inflated cortical reconstruction of E.A.'s brain (lateral and medial views). Note again the robust activation in several posterior ventral occipital areas. Activation for drawing was strong and selective even in the calcarine sulcus. See also (B) for the time courses and magnitude of activation from this area. The time courses are depicted by the following colour index: tactile objects (red), mental imagery (brown), drawing (blue), scribbling (cyan), motor control (orange), and naming/verbal memory (green).

Adapted from Amedi et al. (2008).

included different parts of the brain including frontal cortex (known to be involved with planning and executive functions; Smith and Jonides 1999; Miller 2000) and parietal regions (known to be involved with spatial representation and multisensory integration; Colby and Duhamel 1996; Grefkes et al. 2002; Saito et al. 2003; Amedi et al. 2005; Gobel et al. 2006). Given the known function of these areas, it is perhaps not surprising that they were also active while E.A. drew. Studies in sighted subjects have also revealed strong activity in parietal-frontal networks during drawing tasks (Makuuchi et al. 2003). In the case of both sighted and non-sighted artists, the activity in frontal and parietal regions may correspond to processes that are necessary in drawing such as transformations from perception to two-dimensional image production.

What is perhaps most astonishing is the fact that while E.A. drew pictures, there was also widespread activation in areas within the occipital cortex including primary visual areas—the part of the brain normally used for processing visual information in a sighted person (Figs. 23.2 and 23.3). Given E.A.'s denial of any visual experience, present absolute blindness, and certain early and longstanding profound blindness, it is surprising that his visual cortex area would be active in a skill that is so inherently visual. The specific pattern activation in E.A. implicating 'visual' cortical areas during drawing is consistent with the notion of recruitment of visual areas for non-visual functions. However, this pattern of recruitment is different from other examples of neuroplasticity reported in early blind individuals. Specifically, unlike other early blind subjects (Amedi et al. 2003), E.A. did not show activation of visual cortical areas during the verbal memory task. This might be because he has practised painting and drawing throughout his life and thus the resources of the 'visual' cortex were recruited for this purpose and not for other compensatory behaviours such as verbal memory skills. Consistent with this idea are the facts that E.A. never learned to read Braille and he admittedly reports that his verbal memory skill is, in fact, quite poor. We have previously shown that blind individuals showing superior verbal memory capabilities show maximal plasticity in the visual cortex for this skill while blind subjects having average verbal memory showed modest plasticity (Amedi et al. 2003). The resources offered by the visually deprived visual cortex in early blind subjects are likely inherently limited and thus it is not surprising that extensive and selective training of one skill (drawing in E.A.'s case) may come at the expense of the development of other capacities. A similar scenario exists in the case of proficient Braille readers. The expansion of the brain representation responsible for the preferred reading finger comes at the expense of the representation of adjacent fingers of the same hand (Pascual-Leone and Torres 1993; Sterr et al. 1998). Thus, representation of the preferred reading index finger in the sensorimotor cortex is significantly larger than normal (which is associated with a dramatic increase in precise motor control and tactual perceptual abilities) while the representation of the little finger in the same hand is reduced, apparently encroached upon by the enlarged index finger representation. In a similar manner, recruitment of the 'visual' cortex for drawing may limit the availability of the same brain region for verbal memory or auditory localization, thus accounting for E.A.'s poor verbal memory in the face of his extraordinary drawing abilities (or simply due to the fact that he is not as reliant on his verbal memory).

Another interesting finding is the fact that activation was seen in the occipital cortex while E.A. imagined the objects he drew (albeit at a reduced magnitude of activity). This pattern of activation is also typically seen in normally sighted subjects during visual imagery tasks (Kosslyn et al. 2001, 2005). E.A. is absolutely blind from a very early age, so, what kind of imagery does E.A. posses? Does the sole fact there is activity within visual areas in E.A. during imagery and drawing signify that his experience must inherently be visual, despite his lack of actual vision? These intriguing questions have yet to be answered.

The process of producing an artistic image requires both a technical and creative component. In this study, it is important to note that we attempted to assess the technical aspects of E.A.'s drawing ability and not the source of his creativity. When asked to draw an object, E.A. was given the instruction to reproduce the object on paper and was specifically asked not to attempt to create an 'artistic rendition', but be as faithful to the details as possible. During the scanning, E.A. was given only 15 seconds to produce each object. Thus, our design emphasizes the more direct translation of internal representations as opposed to large-scale creative elements (an interesting topic for future studies). In light of this, we think that it is more likely that we are revealing the nature of E.A.'s internal representation of objects as essentially visual (or at least unequivocally understandable by vision). This is confirmed by the fact that E.A. is able to comprehend the shape of any novel, previously unexplored object by touch alone and quickly and precisely draw it from any vantage point. However, it is possible that E.A. is revealing a remarkable ability to 'translate' into a visual image, a non-visual internal representation of objects.

The study of artistic development in other clinical settings has also revealed many interesting findings and parallels. For example, studies in patients with frontotemporal dementia (FTD; a condition characterized with behavioural symptoms including personality changes and problems with executive function) suggest that this condition can be accompanied by dramatic changes in artistic abilities and expression (Gordon 1999; Drago et al. 2006). Studies of sighted artists have shown dramatic changes in artistic ability and style following focal brain damage (Bogousslavsky 2005). Annoni and colleagues (2005) suggest that new artistic abilities may arise after brain dysfunction, which are dependent upon the lesion site, as well as the ability of the brain to reorganize itself. The occipital activity present in our study of E.A. may demonstrate a similar form of adaptation in a blind painter.

Through his technical and creative skill, E.A. has likewise externalized the workings of a uniquely adapted mind. In a sense, it is perhaps more logical to consider E.A. not so much as a blind individual who has learned to paint but rather, a true artist who just happens to be blind. While there is still much work to be done to elucidate the neural correlates of artistic creativity, this case provides an important contribution to our understanding of the perceptual transformation that must occur when creating visual art. Evidence from this case also supports the hypothesis that internal mental representations can be generated by sensory experiences that are universal in nature (Pascual-Leone and Hamilton 2001). It is possible that the brain may contain more abstract features of object form rather than just simple representations of visual images. Such evidence contributes towards our understanding of the fundamental organization of the human brain, the basis of creativity, as well as the perception of reality.

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