

Drawing on either side of the brain

Ragnhild Magnus and Bruno Laeng

University of Tromsø, Norway

Although both the cerebral laterality of processing visual information and human drawing skill have long been sources of investigation, there is not much empirical work combining the two. In this study, an attempt was made to explore if known different specialisations of the two cerebral hemispheres could help in predicting qualities of drawings produced by each hand. For this purpose, an amateur artist who is able to draw with either the left or the right hand produced a series of realistic drawings of 3D objects. Then 28 participants rated the drawings for several predetermined perceptual and aesthetic properties. The participants judged drawings made with the left hand as superior to those made with the right hand. Given that the right hemisphere controls the left hand, we suggest that this hand might also benefit from the more direct access to lateralised areas that are involved in the processing aspects of visual information and spatial properties (e.g., depth and shading). These perceptual processes may thus play an important role in the ability to draw realistic depictions of objects.

Despite the relevance that drawing has for aesthetic enjoyment, religion, and child play, experimental psychology has produced little research on drawing skills and performance compared, for instance, to the study of object identification from line drawings (e.g., Biederman, 1987; Snodgrass & McCullough, 1986). In the clinical domain, both psychology and neurology have given some attention to drawing as a diagnostic tool of mental disorders and brain damage (Bender, 1938; Hermelin & O'Connor, 1990; Osterrieth, 1944). However, several cognitive neuroscientists have attempted to develop accounts of the brain's basis and cognitive processes of drawing abilities (e.g., Cavanagh, 2005; Chatterjee, 2004; Farah, 1984; Guérin, Ska, & Belleville, 1999; Halverson, 1992; Livingstone, 2002; Roncato, Sartosi, Masterson, & Rumati, 1987; Trojano & Grossi, 1998; van Sommers, 1984, 1989). In addition, in very recent years, neuroimaging research has begun to investigate which brain areas are active during drawing (Makuuchi, Kaminaga, & Sugishita, 2003; Solso, 2000, 2001).

Address correspondence to Bruno Laeng PhD, Department of Psychology, University of Tromsø, Åsgårdveien 9, N-9037 Tromsø, Norway. Email: bruno@psyk.uit.no

In the present study we approach drawing from a cognitive neuroscience perspective. Specifically, we attempt to relate aspects of drawing to underlying lateralised perceptual abilities. In order to accomplish this objective, we used a novel approach based on the analysis of the drawings of an amateur artist who has trained herself to draw model objects with each hand. We asked independent observers to judge the quality of several perceptual properties in drawings of the same object or model, each performed with a different hand (cf. Zacharias & Kirk, 1998).

Our hypotheses are straightforward: Drawing the same object with each hand results in different qualities or perceptual properties in each drawing; these perceptual properties bear a correspondence to known hemispheric specialisation for visuospatial functions. These hypotheses are based on two assumptions:

- (1) The basic human neuroanatomical relations between each hand and each side of the brain; that is, the left hemisphere controls the right hand whereas the right hemisphere controls the left hand, due to the fact that the pyramidal tract fibres as well as the sensory fibres that innervate the hand originate from the opposite hemisphere (Penfield & Boldrey, 1958; Truex & Carpenter, 1969) and that there are costs (slowing and degradation) in transferring information from one hemisphere to the other via the corpus callosum (Ringo, Doty, Demeter, & Simard, 1994), as measured by firing rates of cortical neurons (Gross, Rocha-Miranda, & Bender, 1972) and MRI signals (Tootell, Mendola, Hadjikhani, Liu, & Dale, 1998).
- (2) Each side of the brain appears to be specialised for different visuospatial processes or computations and although there exist individual variations in the pattern of lateralisation of cognitive functions, including visuospatial processes (e.g., Laeng & Peters, 1995), there are also reasons to believe that a basic “blueprint” or a “standard model” of relative lateral advantages is present in the great majority of individuals (e.g., Bradshaw & Nettleton, 1983; Bryden, 1982; Davidson & Hugdahl, 1995; Gazzaniga, Ivry & Mangun, 2002; Hellige, 1996; Hugdahl & Davidson, 2003; Ivry & Robertson, 1998; Kosslyn & Koenig, 1992; Springer & Deutsch, 1998). Moreover, some of these lateralised processes intuitively seem particularly relevant to the cerebral systems implicated in drawing skills. The type of perceptual information that we postulate to be necessary for expert drawing are (1) the perception of edges; (2) the perception of spaces; (3) the perception of relationships; (4) the perception of lights and shadows; and (5) the perception of whole or gestalt.

Visual perception is fundamentally based on the extraction of edges or linear contour information so as to recover the surfaces that constitute the parts of an object (Biederman, 1987; Marr, 1982). Studies of brain-damaged individuals

have shown that patients with right hemisphere damage (Kartsounis & Warrington, 1991; Warrington & Rudge, 1995; Warrington & Taylor, 1973, 1978) have problems in distinguishing real surfaces from projected shadows, line drawings of objects overlapped by other objects, and incomplete drawings, as well as recognising objects seen from unusual or odd angles. In contrast, lesions to the left hemisphere are less likely to cause the above-mentioned problems (McCarthy & Warrington, 1990). Research on normal subjects with the divided visual fields method has also shown that line drawings are generally better perceived by the RH, especially under even more data-limited conditions than the peripheral tachistoscopic presentations involve (e.g., reducing the stimuli's energy or contrast, blurring). Apparently, reductions in perceptibility impair the perceptual abilities of the LH more than those of the RH (Jonsson & Hellige, 1986; Michimata & Hellige, 1987). Consequently, regarding the present study, we would think that left-handed drawing might be superior in depicting the fine details of lines, curves, and edges, of which drawings are indeed made.

Research in neurology has also identified, through tasks like drawing, a handicap called "constructional apraxia" (De Renzi, 1982). Specifically, patients with right hemisphere (RH) lesions often exhibit a loss in appreciating spatial relations among component parts, and problems with reproducing three-dimensionality (Heller, 1994; Poizner, Klima, & Bellugi, 1987). Often these symptoms appear together, or confounded, with spatial hemineglect (Marshall, Lazar, Binder, Desmond, Drucker, & Mohr, 1994), and while RH patients' drawings are scattered, fragmented, and elaborately detailed, the drawings of LH patients appear simplistic and smaller (Larrabee & Kane, 1983) than those of RH patients but they improve more rapidly during recovery from the lesion (Swindell, Holland, Fromm, & Greenhouse, 1988). Kirk and Kertesz (1989) and Zacharias and Kirk (1998) examined the drawings of patients with unilateral lesions and normal controls, which were then analysed by independent observers. Drawings made by normal individuals using their left hand were found to be simpler, more tremulous, and of poorer overall quality than drawings made using the right hand. It was concluded that much of the drawing impairment seen following LH damage is due to an elementary motor disturbance related to use of the non-dominant hand. Stiles-Davis, Janowsky, Engel, and Nass (1988) found that LH-damaged children developed normal drawing abilities, whereas the RH-damaged children were developmentally impaired. In addition, as Gazzaniga and LeDoux (1978) observed from the different performance of each hand of split-brain patients in constructional tasks, the left hand consistently constructed the designs faster than the "preferred" right hand. Gazzaniga and LeDoux specifically interpreted the left-hand advantage as reflecting an RH specialisation for "manipulospacial" activities.

In recent years it has also become clear that the two hemispheres make different contributions to the process of localising and categorising patterns and spatial relations (Kosslyn, Koenig, Barrett, Cave, Tang, & Gabrieli, 1989; see

for a review, Laeng, Chabris, & Kosslyn, 2003). In order to guide movements effectively, the brain needs to represent the precise locations of objects. This “coordinate” type of spatial information is encoded best by the RH, whereas the “categorical” type of spatial information is encoded best by the LH (Hellige & Michimata, 1989; Laeng, 1994; Laeng & Peters, 1995). Hence, we would expect that the two types of spatial representations would consequently affect the way the two hemispheres perceive the structure of an object—and this in turn may have an effect, in our study, on the drawings of each hand (cf. Kosslyn & Koenig, 1992). Specifically, the left-handed drawings should achieve representations that respect best the likeness, symmetry, and proportions of the depicted objects. Another visuospatial aspect that would seem particularly relevant for expert drawing would be the ability to represent empty space (i.e., “negative space” in art theory). Again, this ability would seem to depend on the ability to represent space *per se* (i.e., the metrics of the spaces between objects) in a coordinate spatial framework, which is RH-based.

Recent evidence also indicates that the LH favours the processing of local stimulus properties (e.g., parts of an object or individual items in a scene) whereas the right hemisphere favours processing of global stimulus properties. Ivry and Robertson (1998) have proposed that the two cerebral hemispheres represent global and local information with different levels of fidelity; that is, the RH is biased towards global features of a scene, whereas the LH is biased towards details of local features. Surely, both aspects would seem important for drawing, but we would expect that the left-handed drawings in the present study would better represent global shape, whereas the right-handed drawings would show a complementary superiority in depicting local details in the drawing.

Finally, in drawing, the chiaroscuro effect resulting from the fine cross-hatching or continuous change in grey tones provides much of the realistic sense of tri-dimensionality. Warrington (1982) has shown that patients with RH lesions have more problems in matching the same objects seen under normal and shadowed illumination than LH patients and normal controls. Several studies have shown that depth perception is generally more dependent on areas of the RH than the LH (e.g., Benton & Hécaen, 1970; Carmon & Bechtold, 1969; Danta, Hilton, & O’Boyle, 1978; Fortin, Ptito, Faubert, & Ptito, 2002). One would expect in the present experiment that the left-handed drawings should convey a better sense of the lighting, as well as the volume and depth of an object, than the right-handed drawings.

THE PRESENT STUDY

We hypothesise that the drawings from 3D models executed by an individual with the ability to draw with either hand will show qualitative differences between the two hands’ performance. To assess whether drawings made with each of the artist’s hands are indeed different along several visual properties, we

asked a group of independent observers, who were unaware that drawings were produced by different hands of a same individual, to be the judges of the drawings. Each of the right-handed and left-handed drawings was thus judged with regard to the following visual properties: similarity, depth, details, whole, shadows, skill, pleasantness, and proportions.

Based on a “standard model” of brain lateralisation we hypothesised that the left-handed drawings would be judged better on most of the properties, in particular depth, proportion, whole, similarity, and shadows (cf. McCarthy & Warrington, 1990; Gazzaniga et al., 2002). The right-handed drawings were expected to be superior to the left-handed drawings for “detail”, because of the known left hemisphere preferences for both high-frequency and local stimulus properties (Ivry & Robertson, 1998). Regarding skill, we think that its assessment might strongly depend on the quality of the other visual properties in the drawing. Considering that most of these (i.e., depth, proportion, whole, similarity, and shadows) were hypothesised to be superior in the left-handed drawings, it seems likely that skill would also be judged as superior in these drawings. Finally, we had no specific hypothesis about the property of “pleasantness” of the drawing regarding the two hands, although one could expect that there would be a bias among the judges in rating as pleasant a good (realistic) rendition of the model.

METHOD

Participants

The artist (REM) is a 23-year-old female student of psychology at the University of Tromsø. According to her own report, she has always used her right hand for writing and she does not recall being “forced” to use this hand instead of her left hand. REM’s handedness was assessed with an extended handedness questionnaire (courtesy of Michael Peters, University of Guelph) and with the Edinburgh Handedness Inventory (Oldfield, 1971). The extended handedness questionnaire includes 22 different questions on manual use. For each question there are five choices, ranging from “always left” to “always right”, with a mid-point for “either hand equally well”. REM’s responses indicate a preference for using the right hand (Table 1 shows her responses compared to those of a group of female right-handers and female left-handers of her age; Mean age = 19.3; SD = 2.0). In addition, according to the Edinburgh Handedness Inventory her left hand had a score of 11, while the right hand had a score of 15, indicating a slight right-hand preference. Her parents are both right-handed by self-report, as well as her brother, but one sister was ambidextrous as a child. The grandparents are right-handed, except the paternal grandmother who draws with the left but writes with the right, despite having to retrain the right hand after breaking the arm.

TABLE 1
Hand preference profiles

<i>Action</i>	<i>Right-handed females</i>				<i>Left-handed females</i>				<i>REM</i>
	<i>N</i>	<i>Min</i>	<i>Max</i>	<i>Mean</i> (<i>SD</i>)	<i>N</i>	<i>Min</i>	<i>Max</i>	<i>Mean</i> (<i>SD</i>)	<i>Score</i>
Draw	301	4	5	4.98 (.13)	32	1	1	1.00 (.00)	3
Hold knife	300	1	5	4.74 (.75)	32	1	5	1.94 (1.58)	5
Comb hair	300	2	5	4.32 (.80)	32	1	3	2.25 (.84)	4
Pick up a small object	301	2	5	4.07 (.78)	32	1	3	2.00 (.72)	4
Pick up a book	300	2	5	3.85 (.82)	32	1	4	2.31 (.86)	4
Screw in bulb	292	1	5	4.54 (.75)	32	1	5	2.69 (1.51)	4
Dial a mobile phone	301	1	5	4.49 (.76)	32	1	5	2.44 (1.48)	4
Wave goodbye	301	1	5	4.04 (.85)	32	1	5	2.87 (1.18)	4
Pet a pet	299	2	5	3.64 (.77)	32	1	5	2.69 (.93)	3
Wash face	296	2	5	3.79 (.82)	30	1	3	2.33 (.80)	4
Pick up a heavy object	300	1	5	4.37 (.81)	32	1	5	2.69 (1.18)	4
Pick up a heavy suitcase	301	1	5	4.25 (.88)	32	1	5	2.87 (1.24)	4
Thick end of a baseball bat	287	1	5	4.27 (1.39)	26	1	5	3.08 (1.90)	4
Write	301	4	5	4.98 (.14)	32	1	1	1.00 (.00)	5
Brush teeth	301	1	5	4.71 (.62)	32	1	5	1.81 (1.15)	4
Throw a ball	301	1	5	4.84 (.51)	32	1	5	2.50 (1.72)	4
Hold a tennis racquet	286	1	5	4.66 (.66)	28	1	5	2.21 (1.60)	5
Hold a hammer	298	2	5	4.85 (.41)	32	1	5	2.00 (1.30)	5
Use scissors	301	1	5	4.90 (.40)	32	1	5	2.94 (1.88)	5
Light a match	297	1	5	4.67 (.70)	32	1	5	1.88 (1.34)	3
Sew	297	1	5	4.48 (.97)	32	1	4	1.62 (1.01)	3
Unscrew a jar	300	1	5	4.20 (1.2)	32	1	5	2.37 (1.60)	3

Hand preference profiles of female right-handed writers and female left-handed writers (from the Handedness Database, University of Guelph) and REM's scores on the same hand preference profile (last column).

REM performed some additional tasks aimed at assessing her manual strength and dexterity. Handgrip was measured with a Lafayette Hand Dynamometer (Lafayette, Indiana) four times, in two blocks, according to an ABBA order, switching the initial hand in the second block. The measured strength of the left hand was, in temporal order, 50, 49, 46, and 41 kilograms (mean = 46.5), whereas the right hand's strength was, in temporal order, 52, 59, 54 and 46 kilograms (mean = 52.8). In one of the dexterity tasks, REM was asked to place a dot (with a ballpoint pen) inside a matrix of 240 small circles. Only 10 seconds were allowed for each trial. Each hand performed the same task twice, according to an ABBA ordering, beginning with the left hand. With the left hand REM marked 19 dots in the first trial and 29 in the second trial;

with the right hand 38 dots were marked in the first trial and 43 in the second trial. REM's finger tapping was performed at maximum speed for a period of 15 seconds on each trial on a Veeder-Root (Hartford, Connecticut) counter. The tapping series were repeated four times, in two blocks, according to an ABBA order, switching the initial hand in the second block. The numbers of taps for the left hand were, in temporal order, 65, 57, 57, and 57 (mean = 59; i.e., 3.93 taps/s); whereas numbers of taps for the right hand were, in temporal order, 73, 68, 68, and 60 (mean = 67.3; i.e., 4.49 taps/s). According to the published data of Peters and Durning (1979), both left-handed and right-handed females of the same age as REM did 5.5 taps/s with their preferred hand; with their non-preferred hand, the left-handers did 5.1 taps/s, whereas the right-handed females did 4.8 taps/s. Thus, for REM the difference in taps/s between right and left hand was 0.56, whereas the differences for the control groups of right-handed and left-handed females were 0.7 and 0.4, respectively. These results converge to indicate that REM's right hand is preferred for motor tasks.

REM was also tested with a lateralised lexical decision task. Previous studies have shown robust right visual field advantages in normal subjects (e.g., Chiarello, Seneh, & Soulier, 1986). If a left visual field advantage were to be observed in REM, this could be used as evidence for anomalous brain organisation. The task here consisted of 30 words and 30 pronounceable nonwords of same syllabic length. An ANOVA, with Visual Field (left, right) and Words (real, false) and response times as the dependent variables, showed a significant differences between the visual fields, $F(1, 56) = 7.2$, $p < .01$, with a clear right visual field advantage (mean RT = 612; SD = 481) over the left visual field trials (mean RT = 1029; SD = 579). There was also an interactive effect between the two factors showing no visual field difference (RT difference = 69 ms) for the nonwords and a strong visual field difference for real words (RT difference = 880 ms). A lack of visual field differences for nonwords stimuli has also been described for group performance of both left-handers and right-handers in several previous studies (e.g., Hagenbeek & Van Strien, 2002; Lavidor, Hayes, & Bailey, 2003).

REM enrolled in drawing classes about 3 years ago to improve her skill, but she has been enthusiastic about drawing since childhood. She decided to try to draw with her left hand about 2 years prior to the study, purely out of curiosity, especially after reading B. Edwards's book *Drawing on the right side of the brain* (1979). Apparently, no one specifically encouraged her to try drawing with her left hand, not even during her art classes. At the end of the study REM performed a full intelligence test (WAIS-R; Wechsler, 1981) and obtained a performance IQ of 129 and a verbal IQ of 123 with a full IQ score of 128.

The judges were 28 subjects (age 16–72; 22 were females and 5 were males) who volunteered for a study on art “appreciation”. Half of the participants were psychology students whereas the others were art students or teachers.

Materials

The material consisted of five series of drawings of five different 3D objects (a hand, a pair of feet, a face profile, a toy elephant, and a teapot; see Figure 1 for an example). Each object was drawn four times—according to an ABBA sequence, so as to counterbalance the starting hand and practice effects. The positioning and lighting of the objects were kept constant. All four drawings in a series were drawn in approximately the same time. The range in completing a drawing was 7–20 minutes, and they were completed within the space of 1 week. Specifically, the time to draw the Elephant ranged 15 to 17 minutes and a 6B pencil was used; Hand ranged 12–15 minutes and an artists’ “chark” was used; Feet ranged 10–12 minutes, with charcoal; Teapot ranged 7–9 minutes, with charcoal; Face ranged 17–20 minutes, with charcoal. The drawings were all done on white paper in European paper sizes A3 or A4 (i.e., 29.7×21 cm or 35.5×26.4 cm, respectively). The sizes of the actual drawings were measured along the longest diagonal: the Elephant drawing size ranged 16.8–18.4 cm; Hand ranged 28–31 cm; Feet ranged 28–32; Teapot ranged 19.3–21.2 cm; and Face ranged 22.4–27.6 cm. In addition, photographs were taken with a Nikon Coolpix 5000 digital camera of each of the objects. Each photograph showed the

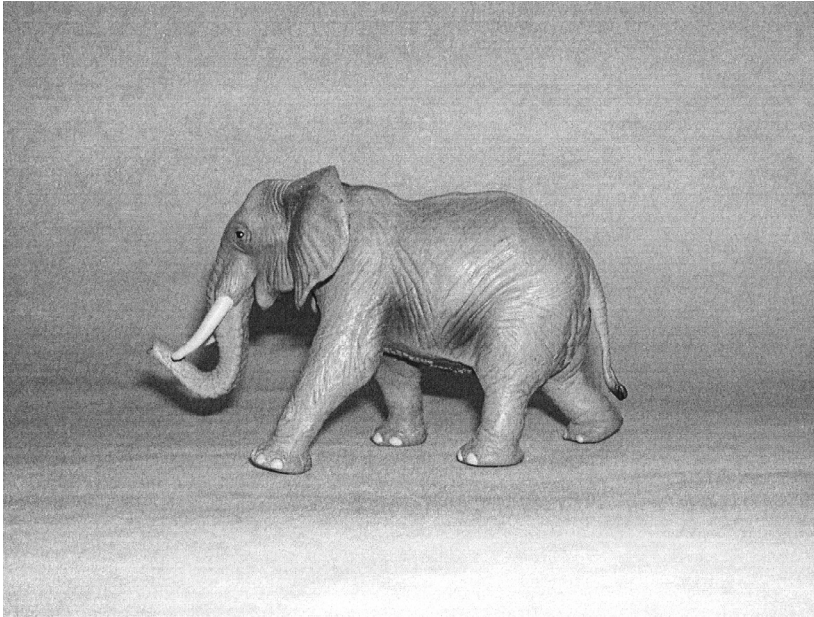


Figure 1. The toy elephant used as one of the models.

objects from the same perspective and distance from the artist (see Figure 2 for examples of the drawings made of the object in Figure 1).

Procedure

The judges were requested to fill out a questionnaire consisting of eight questions, each probing a different visual or aesthetic property; namely, similarity, depth; wholeness; shadow; skill; pleasantness; and proportions. Judges rated each of these properties from 1 to 5; 1 being the lowest and 5 the highest. The questionnaire also included a few biographical items about the age, sex, and handedness of each judge, plus additional questions about their familiarity and expertise with drawing (i.e., if they had experience in drawing, if they liked to draw, if they had had any art classes, and their familiarity with art).

At the beginning of the experiment, each participant received five copies of the questionnaire, each to be filled out for one of the drawing series. It was also explained that more than one drawing could have the same rating and that they should only consider the photograph when answering the first question about similarity. The participants could spend as much time as they wished viewing the material. The drawings in each series were labelled with one of the letters "a", "b", "c", and "d" in the left topmost corner of the paper. The drawings in each series were laid out in the same way for all the participants. The "a" and "b" drawings were laid out beside each other, and the "c" and "d" drawings were laid beside each other beneath the other two.

RESULTS

Judges were grouped according to their expertise with drawing (i.e., whether they had had any art classes or not). The rating results were then subjected to a repeated-measures ANOVA with Expertise (Expert, Naïve) as the between-subjects factor, and Hand (Left, Right), Drawing (Face Feet, Hands, Elephant, Teapot), Properties (Similarity, Depth, Shadow, Details, Whole, Skill, Pleasantness, Proportions), and Copy (First, Second) as the within-subject factors. All data were analysed by use of Statview© software.

There was no effect of Expertise, $F(1, 25) = .02$, or any significant interaction of these factor with the other factors. Mean ratings were higher for the left hand's drawings than the right hand's and the analysis confirmed a statistically reliable main effect of the Hand factor, $F(1, 25) = 133.5$, $p < .0001$. There was also a significant main effect of Drawings, $F(4, 100) = 2.5$, $p < .05$, due to the higher scores for the Elephant drawing compared to those of Face, Feet, and Hand, as well as the higher score of Teapot versus Feet (as confirmed by Fisher's PLSD post-hoc tests). Moreover, there was a significant main effect of Properties, $F(7, 175) = 5.8$, $p < .0001$, as confirmed by Fisher's PLSD post-hoc tests. Similarity scores were significantly lower than those of Skill and Whole and the latter property also received higher scores than Depth, Details,

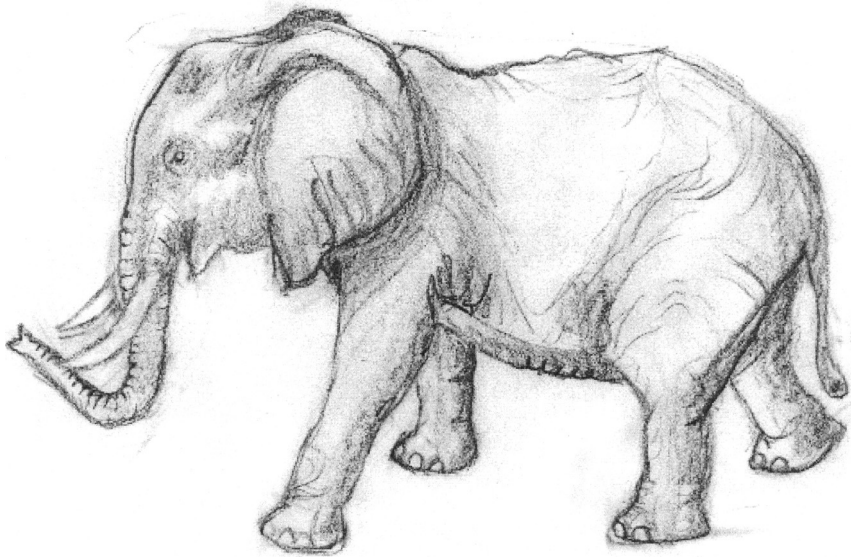
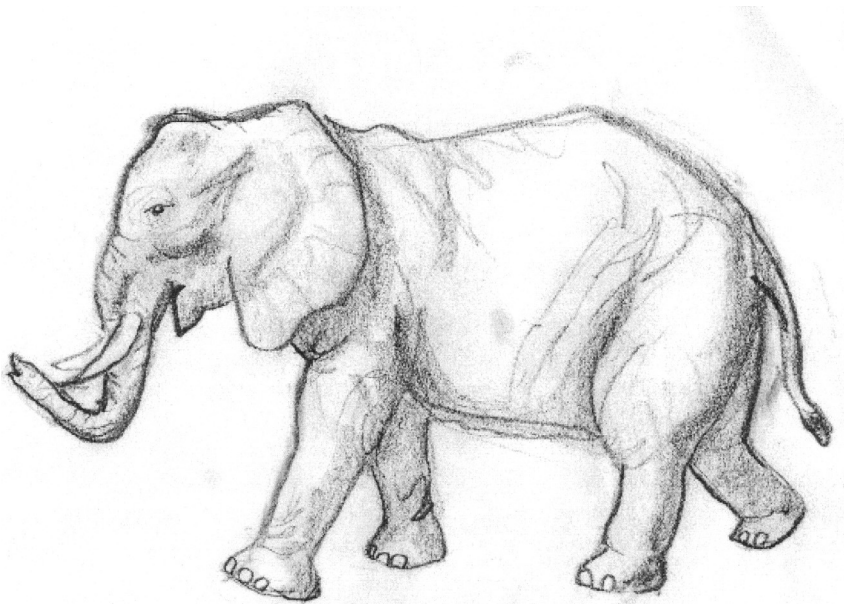
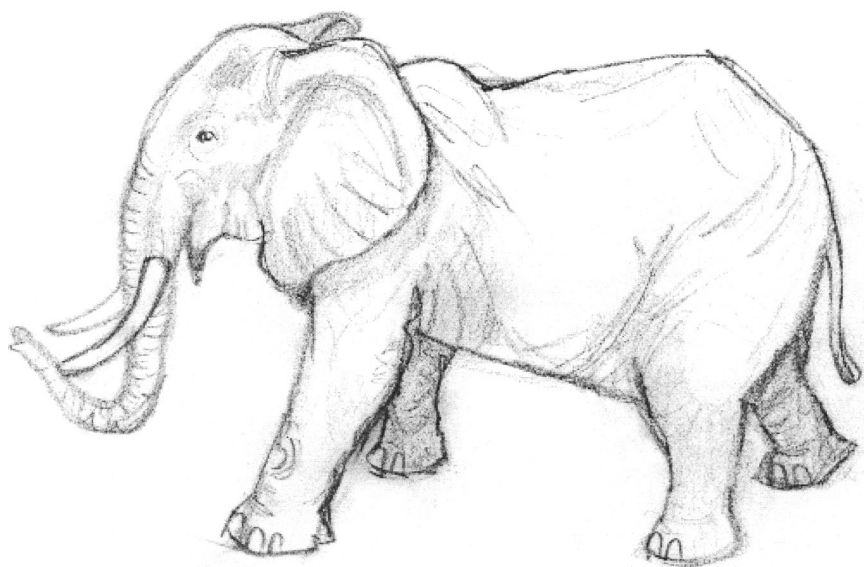
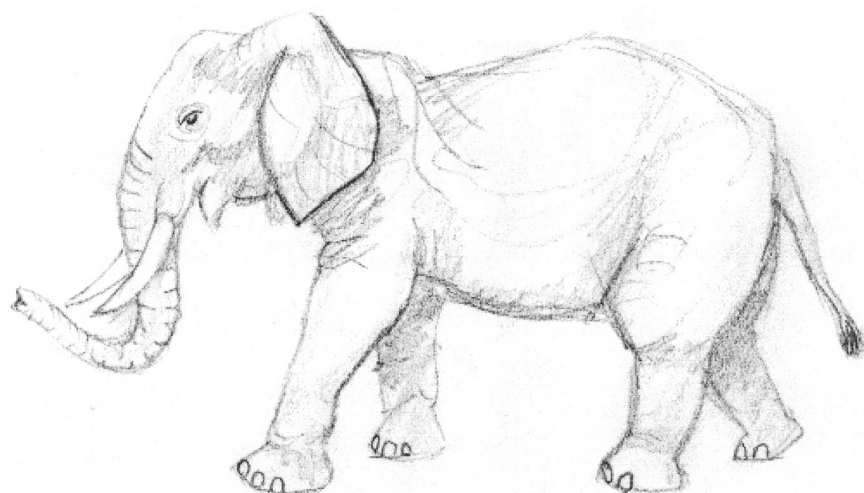


Figure 2. Drawing from the model (of the toy elephant) as made by each hand. Panel A: First left hand drawing. Panel B: Second left hand drawing. Panel C: First right hand drawing. Panel D: Second right hand drawing.



Pleasantness, Proportions, and Shadows. Finally, Skill received higher scores than Pleasantness and Proportions.

There was a significant interactive effect of Hand with Property, $F(7, 175) = 4.1$, $p < .0004$. Figure 3 illustrates means and 95% confidence intervals for this interaction. Finally, there was a significant interaction between Hand and Drawing, $F(4, 100) = 14.6$, $p < .0001$. Table 2 shows the Hand effect for each separate drawing as computed with five separate ANOVAs. Importantly, although the left hand advantage was larger for some drawings than others (the largest different was observed for Elephant and the smallest for Teapot), there was a significant left-hand advantage for every drawing. No other interactive effects were significant.

DISCUSSION

The study sought to assess whether the hands of an artist showed the influence of each hemisphere's "perspective" of the objects. Comparing differences in drawing ability between the two hands of an amateur artist, we found that the two hands produced drawings that were judged, by an independent group of observers, as having less or more of a certain quality (e.g., similarity, depth).

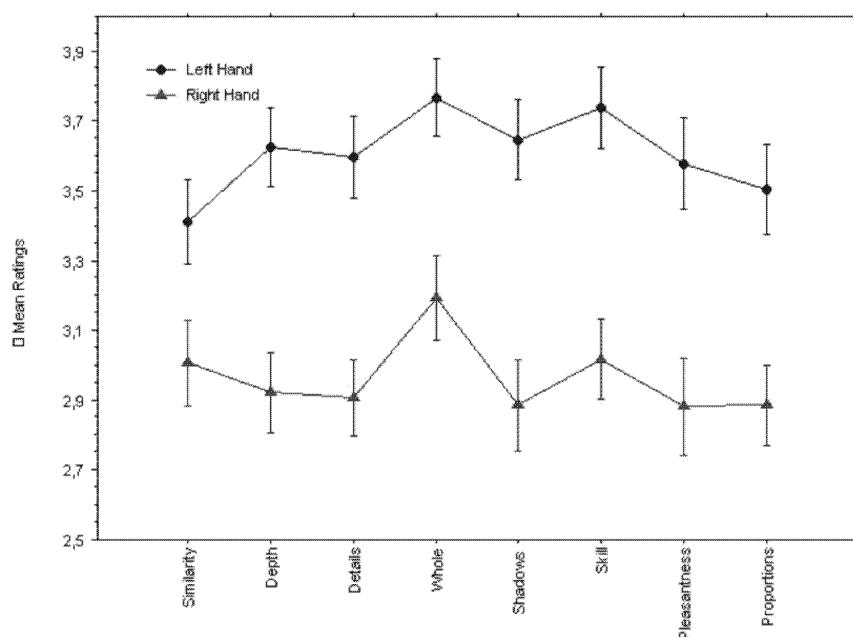


Figure 3. Mean ratings with 95% confidence intervals (bars) for each of the properties split by each hand.

TABLE 2
Mean scores (SDs) for each individual drawing and for the left and right hands

<i>Drawing</i>	<i>Left hand</i>	<i>Right hand</i>	<i>F</i>	<i>P <</i>
Elephant	4.002 (0.88)	2.787 (1.01)	97.6	0.0001
Face	3.560 (0.97)	2.975 (1.01)	19.6	0.0002
Feet	3.330 (1.08)	3.065 (1.02)	6.7	0.01
Hand	3.692 (0.95)	2.746 (1.07)	49.5	0.0001
Teapot	3.458 (1.08)	3.239 (0.98)	6.2	0.02

The last two columns show the *F* value and significance level for the differences between hand scores.

The main finding was that the independent observers clearly judged the presence of a perceptual or aesthetic property more highly in the left-handed drawings than in the right-handed drawings. This preference for the left-handed drawings occurred for all of the probed properties.

The present findings indirectly support the hypothesis that RH's perceptual processes favour successful, realistic drawing. By assuming that the left hand has a more efficient neuroanatomical connection to the cortical areas of the RH supporting perceptual processes, which are hypothesised to be essential for drawing, the present findings of left-hand superiority are clearly consistent with such an account. However, we need to consider that the artist uses the entire visual field and is not under any time constraints that would prevent using the full resources of either hemisphere in collaboration. Nevertheless, one can still posit a left hand–right hemisphere/right hand–left hemisphere correspondence in drawing because some neural pathways are more efficient than others (Elias, Bulman-Fleming, & McManus, 2000; Marzi, Bisiacchi, & Nicoletti, 1991) and, in particular, there is a cost involved in callosum-related transfer of sensory information or motor commands (Ringo et al., 1994; Tootell et al., 1998). Thus, although the artist can use the entire visual field, and both hemispheres obtain the same visual information, each hand remains under the unilateral control of the contralateral hemisphere—this limitation, combined with the cost of callosal transmission, should have a measurable effect on the products of each hand.

Another caveat of the present account is that drawing, in contrast to hand-writing (where the control of movement is very much at the tips of the fingers), not only involves control mechanisms for the fine, distal musculature, but also of the shoulder girdles and upper limbs (for which the cerebral control of movement is more bilateral; cf. Truex & Carpenter, 1969). In the present study, the average size of the drawings exceeded the angle covered by a movement at the joint of the wrist and it certainly involved repositioning of the whole arm in order to continue, for example, the outline of the figure. However, the smaller

parts of the figure as well as fine textural details would seem to mainly involve control mechanisms for the fine, distal musculature. Thus, it is possible that the present drawing involved a combination of unilateral and bilateral control of hand and arm movements. However, bilateral cerebral control of the drawing hand can hardly explain the superiority of one hand over the other in drawing and, therefore, some influence of the hemisphere contralateral to the drawing hand must be taken into account at either the motoric or perceptual level. One possibility that we cannot dismiss is that a less precise control of the left hand may result in less conventional and less photographic but more angular and challenging drawings, and these may please some present-day art connoisseurs who seek the less conventional or less “photographic” renditions. However, there were no differences in the evaluations of the art experts versus those of the naïve observers. Moreover, most of the properties that were required to be judged dealt with the degree of realism in the depiction (e.g., depth and shading) and not, at least directly, with the aesthetic quality of the drawings.

Our account raises many more additional questions: If it is the case that the RH/left hand are superior in drawing, why is there a preponderance of artists who draw with their right hand? And should left-handedness not be a marker of superior drawing abilities? Second, should RH lesions not have devastating effects on an artist’s output? Third, would it be wise to teach students in every art school to draw with the left hand or, in other words, “force” left hand use on right-handers in a similar but opposite way to the traditional doctrine of forcing left-handers to write with the right hand?

Regarding our initial questions, a study by Lanthony (1995) has shown that the prevalence of left-handers among painters (as estimated by direction of the hatching strokes) is actually lower than expected by all measures of the prevalence of left-handedness in the general population (Peters, 1996). Also, there seem to be no clear differences in handedness among individuals who choose different careers (Cosenza & Mingoti, 1993). This evidence is contrary to the popular belief that left-handedness is a marker of artistic genius—e.g., Leonardo Da Vinci is considered by some the prototypical “lefty” genius (Springer & Deutsch, 1998, p. 135), despite the evidence that he may have been born right-handed (see McManus, 2002, pp. 318–320). Additionally, Cosenza and Mingoti’s (1993) study does not support earlier reports (e.g., Mebert & Michel, 1980) concluding that the prevalence of left-handedness is considerably higher among artists than among the general population. Thus, left-handedness might actually not be beneficial to artistic skills or, alternatively, weak or inconsistent hand preference might be to some degree counterproductive for some cognitive functions (Crow, Crow, Done, & Leask, 1998; Nettle, 2003). Perhaps, given the fact that left-handedness can result in deviations from the “standard model” of lateralisation of visuospatial processes (Laeng & Peters, 1995) as well as language-related ones (Wada & Rasmussen, 1960), it can be surmised that an atypical lateralisation is more likely to interfere with learning the skill of drawing.

Regarding the effect of RH versus LH lesions in painters, there is only sparse evidence on the subject. Based on what is available, it seems that while RH lesions can impair (or greatly distort) an artist's skill, LH lesions tend to have rather negligible effects (Gardner, 1982, pp. 318–327). Poizner et al. (1987, pp. 174–175) describe a case of an accomplished artist who suffered RH damage and whose drawings reverted to a child-like output. The often-cited cases of two painters (Raderscheidt and Corinth) who suffered RH stroke demonstrate that, although the artists continued to paint (Schweiger, 1985), there were dramatic changes in their productions. In contrast, studies of painters who suffered LH stroke (and were rendered aphasic) show that the artists continued their creative output unhindered (e.g., Alajouanine, 1948;), with some changes in the symbolism of the post-stroke paintings (e.g., Kaczmarek, 1991), and in some cases even improvement, in the opinion of some critics (Gardner, 1975; Zaimov, Kitov, & Kolev, 1969). Recent research by Snyder and colleagues (Snyder, Mulchay, Taylor, Mitchell, Sachdev, & Gandevia, 2003) with TMS (transcranial magnetic stimulation) suggests that participants' drawings made after pulses were delivered to interfere with their left tempo-parietal lobes, were judged as superior to drawings made after pulses delivered to the right tempo-parietal lobes or in the sham condition. The finding that temporarily "shutting down" the LH improves drawing has prompted the idea that "silencing" the LH's verbal mode helps to uncover the "raw" material of perception unhindered by conceptual processes (cf. Edwards, 1979/2001; Synder & Mitchell, 1999). Finally, a neuroimaging study by Solso (2001) found differences in activation in the right posterior parietal areas of skilled artists compared to novices, when both were engaged in drawing portraits. The parietal lobe was activated in both the artist and the novice, but the activation in the novice was somewhat greater. A lower level of activation was interpreted as a more efficient way of processing.

In relation to our third question, it seems to us that it would be just as unwise to teach or force right-handers to draw with the left hand as to force left-handers to write with their right hands. The main reason might be that the costs involved in loss of accurate motor control might be greater than any of the benefits accrued in using the hand directly innervated by the RH. Hence, the advantages of left-handed drawing might only be revealed in individuals who already have a weak and inconsistent preference for one hand over the other in most unimanual tasks (cf. Nakano, Endo, & Tanaka, 2003). Although Cohen and Bennett (1997) proposed that it is a draughtsman's misconception of the objects, and not motor coordination, that is the major source of inaccuracies when drawing, it seems plausible that a large difference in fine motor coordination between the two hands would overshadow the benefits of reduced perceptual inaccuracies. Nevertheless, there have been champions of the idea of encouraging ambidexterity (Baden Powell, the founder of the Boy Scout movement, was one famous supporter of this idea and, as a result, Boy Scouts shake hands with the

left hand; Corballis, 1993, p. 90). There are also art teachers who do recommend switching the pencil to the left hand (Edwards, 1979/2001, p. 45; cf. Harris, 1988) and there exist art students who spontaneously choose to do so (as the amateur artist investigated here).

Finally, it remains unclear why, in the present study, all of the probed aspects resulted in superiority of the left-handed compared to the right-handed drawings. In particular, it is not clear why “details” were not better represented in the right-handed drawings. One possibility could be that some of the other RH-based perceptual properties contributed to a better representation of the detailed edges and contours. For example, the chiaroscuro representation of depth and self-cast shadows might in itself engender the impression that the object has been represented in greater detail. Of course, we cannot reject another account suggesting that our artist had a somewhat atypical brain lateralisation compared to that based on the “standard model”. However, both her handedness and lexical laterality profile indicated no departure from the typical right-hander’s profile. Moreover, it is remarkable how well the standard model was able overall to predict the qualities of different perceptual properties in the artist’s drawings.

Manuscript received 18 February 2005

Revised manuscript received 15 August 2005

REFERENCES

- Alajouanine, T. (1948). Aphasia and artistic realization. *Brain*, 71, 229–241.
- Bender, L. (1938). A visual motor Gestalt test and its clinical use. *American Orthopsychiatric Association, Research Monographs*, No. 3.
- Benton, A. L., & Hecaen, H. (1970). Stereoscopic vision in patients with unilateral cerebral disease. *Neurology*, 20, 1084–1088.
- Biederman, I. (1987). Recognition-by-components: A theory of human image understanding. *Psychological Review*, 94, 115–147.
- Bradshaw, J. L., & Nettleton, N. C. (1983). *Human cerebral asymmetry*. Englewood Cliffs, NJ: Prentice-Hall Inc.
- Bryden, M. P. (1982). *Laterality: Functional asymmetry in the intact brain*. New York: Academic Press.
- Carmon, A., & Bechtold, H. P. (1969). Dominance of the right hemisphere for stereopsis. *Neuropsychologia*, 7, 29–40.
- Cavanagh, P. (2005). The artist as neuroscientist. *Nature*, 434, 301–307.
- Chatterjee, A. (2004). The neuropsychology of visual artistic production. *Neuropsychologia*, 42, 1568–1583.
- Chiarello, C., Senh, J., & Soulier, M. (1986). Viewing conditions and hemisphere asymmetry for the lexical decision. *Neuropsychologia*, 24, 521–529.
- Cohen, D. J., & Bennett, S. (1997). Why can’t most people draw what they see? *Journal of Experimental Psychology*, 23, 609–621.
- Corballis, P. (1993). *The lopsided ape*. New York: Oxford University Press.
- Cosenza, R. M., & Mingoti, S. A. (1993). Career choice and handedness: A survey among university applicants. *Neuropsychologia*, 31, 487–497.

- Crow, T. J., Crow, L. R., Done, D. J., & Leask, S. (1998). Relative hand skill predicts academic ability: Global deficits at the point of hemispheric indecision. *Neuropsychologia*, 36, 1275–1282.
- Danta, G., Hilton, R. C., & O'Boyle, D. J. (1978). Hemisphere function and binocular depth perception. *Brain*, 101, 569–589.
- Davidson, R. J., & Hugdahl, K. (1995). *Brain asymmetry*. Cambridge, MA: The MIT Press.
- De Renzi, E. (1982). *Disorders of space exploration and cognition*. Chichester, UK: John Wiley & Sons.
- Edwards, B. (1979/2001). *Drawing on the right side of the brain*. London: HarperCollins Publishers.
- Elias, L. J., Bulman-Fleming, M. B., & McManus I. C. (2000). Linguistic lateralisation and asymmetries in interhemispheric transmission time. *Brain and Cognition*, 43, 181–185.
- Farah, M. J. (1984). The neurological basis for mental imagery: A componential analysis. *Cognition*, 18, 245–272.
- Fortin, A., Ptito, A., Faubert, J., & Ptito, M. (2002). Cortical areas mediating stereopsis in the human brain: A PET study. *NeuroReport*, 13, 895–898.
- Gardner, H. (1975). *The shattered mind: The person after brain damage*. New York: Alfred A. Knopf.
- Gardner, H. (1982). *Art, mind and brain*. New York: Basic Books.
- Gazzaniga, M. S., Ivry, R., & Mangun, G. (2002). *Cognitive neuroscience: The biology of the mind*. New York: Norton & Company.
- Gazzaniga, M. S., & LeDoux, J. E. (1978). *The integrated mind*. New York: Plenum Press.
- Gross, C. G., Rocha-Miranda, C. E., & Bender, D. B. (1972). Visual properties of neurons in inferotemporal cortex of the macaque. *Journal of Neurophysiology*, 35, 96–111.
- Guérin, F., Ska, B., & Belleville, S. (1999). Cognitive processing of drawing abilities. *Brain and Cognition*, 40, 464–478.
- Hagenbeek, R. E., & Van Strien, J. W. (2002). Left–right and upper–lower visual field asymmetries for face matching, letter naming, and lexical decision. *Brain and Cognition*, 49, 34–44.
- Halverson, J. (1992). The first pictures: Perceptual foundations of Paleolithic art. *Perception*, 21, 389–404.
- Harris, L. J. (1988). Right-brain training: Some reflections on the application of research on cerebral specialisation to education. In D. Molfese & S. J. Segalowitz (Eds.), *Developmental implications of brain lateralisation* (pp. 207–235). New York: Guilford Press.
- Heller, W. (1994). Cognitive and emotional organization of the brain: Influences on the creation and perception of art. In D. Zaidel (Ed.), *Neuropsychology* (pp. 271–292). New York: Academic Press.
- Hellige, J. B. (1996). Hemispheric asymmetry for visual information processing. *Acta Neurobiologica Experimentalis*, 56, 485–497.
- Hellige, J. B., & Michimata, C. (1989). Categorisation versus distance: Hemispheric differences in processing spatial information. *Memory and Cognition*, 17(6), 770–776.
- Hermelin, B., & O'Connor, N. (1990). Art and accuracy: The drawing ability of idiots-savants. *Journal of Child Psychology and Psychiatry*, 31, 217–228.
- Hugdahl, K., & R. J. Davidson (2003). *The asymmetrical brain*. Cambridge, MA: The MIT Press.
- Ivry, R. B., & Robertson, L. C. (1998). *The two sides of perception*. Cambridge, MA: The MIT Press.
- Jonsson, J. E., & Hellige, J. B. (1986). Lateralised effects of blurring: A test of the visual spatial frequency model of cerebral hemisphere asymmetry. *Neuropsychologia*, 24, 351–362.
- Kaczmarek, B. (1991). Aphasia in an artist: A disorder of symbolic processing. *Aphasiology*, 5, 361–371.
- Kartsounis, L. D., & Warrington, E. K. (1991). Failure of object recognition due to a breakdown of figure–ground discrimination in a patient with normal acuity. *Neuropsychologia*, 29, 969–980.
- Kirk, A., & Kertesz, A. (1989). Hemispheric contributions to drawing. *Neuropsychologia*, 27, 881–886.

- Kosslyn, S. M., & Koenig, O. (1992). *Wet mind: The new cognitive neuroscience*. New York: The Free Press.
- Kosslyn, S. M., Koenig, O., Barrett, A., Cave, C. B., Tang, J., & Gabrieli, J. D. E. (1989). Evidence for two types of spatial representations: Hemispheric specialisation for categorical and coordinate relations. *Journal of Experimental Psychology: Human Perception and Performance*, 15(4), 723–735.
- Laeng, B. (1994). Lateralisation of categorical and coordinate spatial functions: A study of unilateral stroke patients. *Journal of Cognitive Neuroscience*, 6, 189–203.
- Laeng, B., Chabris, C. F., & Kosslyn, S. M., (2003). Asymmetries in encoding spatial relations. In K. Hugdahl & R. J. Davidson (Eds.), *The asymmetrical brain* (pp. 303–340). Cambridge, MA: The MIT Press.
- Laeng, B., & Peters, M. (1995). Cerebral lateralisation for the processing of spatial coordinates and categories in left- and right-handers. *Neuropsychologia*, 33, 421–439.
- Lanthony, P. (1995). Les peintres gauchers. *Revue Neurologique*, 151, 165–170.
- Larrabee, G. J., & Kane, R. L. (1983). Differential drawing size associated with unilateral brain damage. *Neuropsychologia*, 21, 173–177.
- Lavidor, M., Hayes, A., & Bailey, P. J. (2003). Handedness, measures of hemispheric asymmetry, and lateralised lexical decision. *Laterality*, 8, 347–360.
- Livingstone, M. (2002). *Vision and art: The biology of seeing*. New York: Harry N. Abrams, Inc.
- Makuuchi, M., Kaminaga, T., & Sugishita, M. (2003). Both parietal lobes are involved in drawing: A functional MRI study and implications for constructional apraxia. *Cognitive Brain Research*, 16, 338–347.
- Marr, D. (1982). *Vision: A computational investigation into the human representation and processing of visual information*. New York: W. H. Freeman.
- Marshall, R. S., Lazar, R. M., Binder, J. R., Desmond, D. W., Drucker, P. M., & Mohr, J. P. (1994). Intrahemispheric localization of drawing dysfunction. *Neuropsychologia*, 32, 493–501.
- Marzi, C. A., Bisiacchi, P., & Nicoletti, R. (1991). Is interhemispheric transfer of visuomotor information asymmetric? Evidence from a metanalysis. *Neuropsychologia*, 29, 1163–1177.
- McCarthy, R. A., & Warrington, E. K. (1990). *Cognitive neuropsychology: An introduction*. London: Academic Press, Inc.
- McManus, C. (2002). *Right hand, left hand: The origins of asymmetries in brains, bodies, atoms and cultures*. Cambridge, MA: Harvard University Press.
- Mebert, C., & Michel, G. (1980). Handedness in artists. In J. Herron (Ed.), *Neuropsychology of left handedness*. New York: Academic Press.
- Michimata, C., & Hellige, J. B. (1987). Effects of blurring and stimulus size on the lateralised processing of nonverbal stimuli. *Neuropsychologia*, 25, 397–407.
- Nakano, M., Endo, T., & Tanaka, S. (2003). A second Leonardo da Vinci? *Brain and Cognition*, 53, 9–14.
- Nettle, D. (2003). Hand laterality and cognitive ability: A multiple regression approach. *Brain and Cognition*, 52, 390–398.
- Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh Inventory. *Neuropsychologia*, 9, 97–114.
- Osterrieth, P. A. (1944). Le test de copie d'une figure complexe. *Archives de Psychologie*, 30, 206–356. [Translated by J. Corwing & F. W. Bylsma (1993). *The Clinical Neuropsychologist*, 7, 9–15.]
- Penfield, W., & Boldrey, E. (1958). Somatic and sensory representation in the cerebral cortex as studied by electrical stimulation. *Brain*, 60, 389–443.
- Peters, M. (1996). Handedness and its relation to other indices of cerebral lateralisation. In R. J. Davidson & K. Hugdahl (Eds.), *Brain asymmetries*. Cambridge, MA: The MIT Press.
- Peters, M., & Durdington, B. M. (1978). Handedness measured by finger tapping: A continuous variable. *Canadian Journal of Psychology*, 32, 257–260.

- Poizner, H., Klima, E. S., & Bellugi, U. (1987). *What the hands reveal about the brain*. Cambridge, MA: The MIT Press.
- Ringo, J. L., Doty, R. W., Demeter, S., & Simard, P. Y. (1994). Time is of the essence: A conjecture that hemispheric specialisation arises from interhemispheric conduction delay. *Cerebral Cortex*, 4, 331–343.
- Roncato, S., Sartosi, G., Masterson, J., & Rumati, R. (1987). Constructional apraxia: An information processing analysis. *Cognitive Neuropsychology*, 4, 113–129.
- Schweiger, A. (1985). Harmony of the spheres and the hemispheres: The arts and hemispheric specialisation. In F.D. Benson & E. Zaidel (Eds.), *The dual brain: Hemispheric specialisation in humans*. New York: Guilford Press.
- Snodgrass, J. G., & McCullough, B. (1986). The role of visual similarity in picture categorisation. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 12, 147–154.
- Snyder, A. W., & Mitchell, J. (1999). Is integer arithmetic fundamental to mental processing? The mind's secret arithmetic. *Proceedings of the Royal Society: Biological Sciences*, 266, 587–592.
- Snyder, A. W., Mulchay, E., Taylor, J. L., Mitchell, D. J., Sachdev, P., & Gandevia, S. C. (2003). Savant-like skills exposed in normal people by suppressing the left fronto-temporal lobe. *Journal of Integrative Neuroscience*, 2, 149–158.
- Solso, R. L. (2000). The cognitive neuroscience of art. *Journal of Consciousness Studies*, 7, 75–85.
- Solso, R. L. (2001). Brain activities in a skilled versus novice artists: An fMRI study, *Leonardo*, 34, 31–34.
- Springer, S. P., & Deutsch, G. (1998). *Left brain, right brain: Perspectives from cognitive neuroscience*. New York: W.H. Freeman & Company.
- Stiles-Davis, J., Janowsky, J., Engel, M., & Nass, R. (1988). Drawing ability in four young children with congenital unilateral brain lesions. *Neuropsychologia*, 26, 359–371.
- Swindell, C. S., Holland, A. L., Fromm, D., & Greenhouse, J. B. (1988). Characteristics of recovery of drawing ability in left and right brain-damaged patients. *Brain and Cognition*, 23, 16–30.
- Tootell, R. B. H., Mendola, J. D., Hadjikhani, N. K., Liu, A. K., & Dale, A. M. (1998). The representation of the ipsilateral visual field in human cerebral cortex. *Proceedings of the National Academy of Sciences, USA*, 95, 818–824.
- Trojano, L., & Grossi, D. (1998). 'Pure' constructional apraxia: A cognitive analysis of a single case. *Behavioural Neurology*, 11, 43–49.
- Truex, R. C., & Carpenter, M. B. (1969). *Human neuroanatomy*. Baltimore: Williams & Wilkins.
- van Sommers, P. (1984). *Drawing and cognition*. New York: Cambridge University Press.
- van Sommers, P. (1989). A system for drawing and drawing-related neuropsychology. *Cognitive Neuropsychology*, 6, 117–164.
- Wada, J. A., & Rasmussen, T. (1960). Intra-carotid injection of sodium amylal for the lateralisation of cerebral speech dominance. *Journal of Neurosurgery*, 17, 266–282.
- Warrington, E. K. (1982). Neuropsychological studies of object recognition. *Philosophical Transactions of the Royal Society of London, Series B*, 295, 411–423.
- Warrington, E. K., & Rudge, P. (1995). A Comment on apperceptive agnosia. *Brain and Cognition*, 28, 173–177.
- Warrington, E. K., & Taylor, A. M. (1973). The contribution of the right parietal lobe to object recognition. *Cortex*, 9, 152–164.
- Warrington, E. K., & Taylor, A. M. (1978). Two categorical stages of object recognition. *Perception*, 7, 695–705.
- Wechsler, D. (1981). *WAIS-R manual*. New York: The Psychological Corporation.
- Winner, E. (1982). *Invented worlds: The psychology of the arts*. Cambridge, MA: Harvard University Press.
- Zacharias, S., & Kirk, A. (1998). Drawing with the non-dominant hand: Implications for the study of construction. *Canadian Journal of Neurological Science*, 25, 306–309.
- Zaimov, K., Kitov, D., & Kolev, N. (1969). Aphasie chez un peintre. *Encephale*, 68, 377–417.