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Leftward spatial bias in children’s drawing placement: Hemispheric activation versus directional hypotheses

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A leftward spatial bias in drawing placement was demonstrated by Heller (1991) using the draw-a-person test with right-handed American children. No such bias was observed in left-handed children who are assumed to be less lateralised than their right-handed peers. According to Heller the leftward spatial bias is primarily a reflection of the right hemisphere specialisation for spatial processing. However, an alternative explanation in terms of directional trends may be put forward. In the present study we first confirm Heller’s findings of a handedness effect on drawing placement using the draw-a-tree task with a large sample of right- and left-handed French children aged 5–15 years (Exp. 1). We then provide evidence that a similar leftward bias occurs in right-handed Moroccan children aged 7–11 years with opposite script directionality and opposite preferred drawing movement directions (i.e., right-to-left directional trends) to the those of right-handed French children (Exp. 2). Taken together these findings suggest that directionality trends arising from learned cultural habits and motor preferences play little role in determining spatial bias in the centring of a single object drawn on a page. Rather there may be a cerebral origin for drawing single objects slightly on the left side of the graphic space.

Keywords: Spatial bias; Drawing; Children; Culture.

Spatial bias has been shown to occur in brain-intact participants performing a variety of visual-spatial graphomotor tasks, such as tasks involving line bisection (for a review see Jewell & McCourt, 2000), the illustration of spatial/temporal events (e.g., drawing active sentences with directional actions, Maass & Russo, 2003; drawing objects in spatial relation, Vaid, Rhodes, Tosun, & Eslami, 2011), or even the drawing of single objects on the
A common finding is that right-handed participants from Western countries tend to bisect lines leftward from their actual centre (Bradshaw, Nathan, Nettleton, Wilson, & Pierson, 1987). When illustrating spatial/temporal events they tend to locate the sentence subject to the left of the object (Barrett & Craver-Lemley, 2008; Chatterjee, Maher, & Heilman, 1995; Chatterjee, Southwood, & Basilico, 1999; Geminiani, Bisiach, Berti, & Rusconi, 1995), and tend to locate a near object to the front left of a more distant object (Braine, Schauble, Kugelmass, & Winter, 1993; Vaid et al., 2011). Finally, when asked to draw single objects on a page they tend to draw objects facing leftward (Karev, 1999; Kebbe & Vinter, 2013; Picard, 2011; van Sommers, 1984; Viggiano & Vannucci, 2002), and tend to draw objects slightly leftward from the actual centre of the page (Heller, 1991; Barrett & Craver-Lemley, 2008; Barrett et al., 2002).

In general, the leftward spatial bias has been accounted for by the hemispheric specialisation hypothesis (Bradshaw et al., 1987), which posits that the spatial nature of the task to be performed induces a preferential activation of the specialised (right) hemisphere, which in turn leads to an enhancement of the left perceived hemispace, thereby inducing an attentional bias to the left (Kinsbourne, 1970). For instance, Heller (1991) conducted a study in which she used the draw-a-person test as a mean to assess implicit visuo-spatial bias in American children aged 4–14 years. She found that, irrespective of age, right-handed children demonstrated a bias towards the left side of the graphic space, contralateral to the specialised hemisphere. By contrast, no such bias was observed in left-handed children, a finding congruent with the view that left-handers are usually less lateralised than right-handers (for a review see Bradshaw & Nettleton, 1983). Accordingly, Heller suggested that the leftward bias of right-handers “is primarily a reflection of right-hemisphere specialisation for spatial processing” (1991, p. 157).

However, the hemispheric specialisation hypothesis has been challenged by a series of studies, mostly cross-cultural, showing that directionality trends, relative to directionality of written language (cultural factors) and/or preferred movement directions (motor factors), also play a role in how participants respond to visual-spatial computation tasks. Cross-cultural studies have compared behavioural outcome of participants performing visual-spatial graphomotor tasks from at least two different cultures differing in script directionality (mostly left-to-right versus right-to-left horizontal scripts). These studies allowed a comparison between the hemispheric specialisation view of the origin of spatial biases (which predicts a left hemispatial bias regardless of script directionality) and the directional trend account of the origin of spatial biases (which predicts opposite patterns of spatial biases across cultures). As we will discuss later, some of
these studies have also considered the role of biomechanical factors by studying the influence of handedness and reading/writing habits together (see for instance Vaid, 1998).

As a whole, cross-cultural studies have provided mixed evidence regarding the prominent role of script directionality in spatial biases. For instance, in line bisection tasks, opposite patterns of deviations were observed in readers from left to right (French) and readers from right to left (Israeli), with the latter group bisecting lines rightward from their actual centre (Chokron & DeAgostini, 1995; Chokron & Imbert, 1993; but for no replication of these findings see Barrett et al., 2002; Speedie et al., 1995;). In sentence illustration tasks a reversal of directional bias was observed in Arab students whose first learned language was right to left: these participants tended to locate the agent rightward of the object (Maass & Russo, 2003; but for no relationship between the direction of reading and the location of agents and objects in a similar sentence illustration task see Altmann, Saleem, Kendall, Heilman, & Gonzales Rothi, 2006; Barrett et al., 2002). When asked to draw the arrow of time, French children with no experience of the written Arabic system were found to use a left-to-right direction, whereas Moroccan children mostly favoured a right-to-left direction congruent with the directionality of their cultural script (Troade & Zarhbouch, 2011; Zarhbouch & Troade, 2006). In a depth depiction task (drawing a scene containing two houses, a near one and a far one), opposite patterns of drawing placements were found in English readers, who mostly located the near house on the left side of the page, and Arabic readers, who showed a slight right bias placement of the near house (Vaid et al., 2011). In tasks involving the drawing of single objects a recent cross-cultural study by Kebbe and Vinter (2013) showed a leftward directional bias in French participants and a rightward bias in Syrian participants (right-to-left reading habits) in drawing side-view objects. Interestingly, this opposite pattern of results was observed at ages 8 and 10, as well as in adults, but not at age 6, suggesting that the effects of reading and writing habits on drawing directionality may be mostly noticeable after age 7 when children enter the formal learning of reading and writing their language. The above-mentioned cross-cultural studies have pointed to the need to consider directionality trends arising from reading and writing habits as either major or additional sources of influence on spatial biases. However, none of them actually offers conclusive results regarding a cultural origin of these spatial biases.

Directionality trends not solely arise from cultural factors relative to reading and writing habits, but are also shaped by biomechanical factors relative to preferred movement directions. This motor factor is worth considering insofar as it might play either in concert with or in opposition to scanning habits due to script directionality. In Western countries, right-handed drawers are known to proceed more easily in a left-to-right direction
whereas left-handers tend to proceed in an opposite direction while drawing (see Goodnow & Levine, 1973; Picard, 2011; van Sommers, 1984). These preferred directions are congruent with the fact that hand movements directed away from the body (outward or extensor movements) are performed more easily than those directed towards the body (inward or tensor movements; Dreman, 1974; van Sommers, 1984), and maximise visibility of the ongoing graphic traces. Thus, in Western countries, directionality trends due to script directionality and preferred movement directions play in concert in right-handed participants (left-to-right direction), whereas they conflict for left-handers. Interestingly, when the cultural background imposes a right-to-left reading/writing habit, script directionality may supersede the natural motor tendencies in right-handed participants at least. In this case, numerous studies have shown that right-handed participants with a right-to-left script tend to draw horizontal lines from right to left (Lieblich, Ninio, & Kugelmass, 1975; Nachshon, 1981), tend to proceed using a right-to-left stroke direction when drawing objects (Vaid, Singh, Sahuja, & Gupta, 2002), and tend to draw objects facing rightward (Vaid, 1995; Kebbe & Vinter, 2013). Thus, in cultures with right-to-left reading/writing habits, directionality trends due to script directionality force right-handed participants to adopt right-to-left movement directions for drawing—or, put differently, to behave like left-handers in their drawing movements.

To summarise, there is still a debate on the origin (cerebral, cultural, biomechanical) of spatial biases in graphomotor behaviour, and the underlying mechanisms (right hemispheric activation, directional trends), that calls for further investigations. We designed the present study to test the concurrent hypotheses of hemispheric activation and directional trends that may account for the leftward spatial bias observed in drawing placement (Heller, 1991). We decided to focus on this implicit page-centring task for two main reasons. First, while most studies on spatial bias have used explicit tests of visual-spatial computations (the line bisection task is a typical example of such tasks), only a few of them have relied on more implicit tests, such as the page-centring task in which participants have to draw an object on a page and in which drawing displacement from the actual centre is taken as a measure of spatial bias (Barrett & Craver-Lemley, 2008; Barrett et al., 2002; Heller, 1991). According to Barrett this understudied task “measures an implicit tendency to act in a spatially asymmetric manner”, and “may assess spatial bias at a more fundamental level, or it may be more sensitive means of examining visual-spatial bias” (Barrett et al., 2002, p. 1011). Second, the leftward bias found by Heller (1991) with right- but not left-handed children is interpretatively ambiguous: it can be mediated by brain organisation (as suggested by the author herself), as well as by directional trends, or by both factors in combination. Indeed, as we have discussed
above, directional trends arising from both reading/writing habits and preferred movement directions play in concert in right-handed participants with a left-to-right script, whereas they play in the opposite direction for left-handers. As a result, the possibility cannot be ruled out that converging directional trends in right-handers generate a leftward spatial bias in drawing placement, while diverging directional trends in left-handers reduce magnitude bias up to a point where drawing displacement is not significantly different from zero. Furthermore, directionality trends may act independently of any impact of brain organisation or they may act in combination with it, thus leaving the above-mentioned debate entirely open.

In order to test the concurrent hypotheses of hemispheric activation and directional trends that may account for the leftward spatial bias observed in drawing placement, we first attempted to replicate Heller’s finding of a handedness effect on spatial bias in drawing placement using the draw-a-tree task with French children (Experiment 1). Then we tested the possible role of directionality trends by comparing spatial bias in children with opposite directional trends (French and Moroccan right-handed children) (Experiment 2). Our predictions were as follows. First, in line with Heller’s findings, a leftward spatial bias should be observed in right-handed children, but not in left-handed children, irrespective of their age (Experiment 1). Second, if the leftward spatial bias is mostly a reflection of hemispheric specialisation, a similar leftward bias should emerge in drawings made by both cultural groups, irrespective of their opposite directionality trends (Experiment 2). By contrast, if the bias has roots in directional trends, the two cultural groups should display opposite spatial biases (leftward for French children, rightward for Moroccan children); additionally, in both cultural groups, size of spatial bias might possibly increase with increasing age if exposure to reading/writing habits is a main factor of influence (see Kebbe & Vinter, 2013). Finally, in cases where both right hemispheric activation and directional trends played a role in determining the leftward spatial bias different, but not symmetrical, biases would emerge in the two cultural groups, with a possible weaker-in-magnitude leftward bias in Moroccan children due to their directional trends acting counter to the cerebral tendencies.

**EXPERIMENT 1: SPATIAL BIAS IN DRAWING PLACEMENT BY RIGHT- AND LEFT-HANDED CHILDREN**

**Method**

We aimed to replicate Heller’s finding of a handedness effect on spatial bias in drawing placement, using the draw-a-tree task with a sample of French children and adolescents aged 5–15 years. The tree drawing was selected as
this object has no profile, is quite symmetrical, can easily be drawn from an early age by children (5 years), and is a common component of drawing instruments used by clinical psychologists (Buck, 1948). Also, studies by Barrett and colleagues (Barrett & Craver-Lemley, 2008; Barrett et al., 2002) have shown that spatial bias in drawing placement not only occurred for person drawing, but also extend to tree drawing, at least as far as right-handed adults are concerned.

**Rationale.** If results obtained by Heller (1991) with person drawing extend to drawings of a tree produced by French children, it was expected that the right-handed children would show a leftward spatial bias whereas the left-handed children would show no significant spatial bias in the implicit page-centring task, whatever their age (and exposure to left-to-right script).

**Procedure.** A total of 106 brain-intact children and adolescents aged 5 to 15 years took part in Experiment 1. Participants differed on handedness which was assessed prior to the study, using the shortened version of the Edinburgh Handedness Inventory (Oldfield, 1971): half were consistently right-handed and the other half were consistently left-handed (see Table 1). Participants came from middle-class districts of southern French cities, and were recruited from elementary schools and middle schools: they were from 10 school levels, from kindergarten to Grade 9, with approximately five participants per school level and handedness. None of them was known to suffer from a psychiatric or psychomotor disorder. All were native French and had a left-to-right reading/writing habit, but the adolescents had more reading/writing experience than the children due to their higher school level. Written parental consent was obtained for each participant and the study was carried out in accordance with the Declaration of Helsinki – Sixth Revision (2008).

Individual white paper sheets, a normal crayon (HB), and nine coloured crayons were used as materials for the drawing task. Each participant was asked to draw a tree (from memory) within a delimited graphic space

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Experiment 1: Participant characteristics and measures of drawing displacement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Handedness</td>
<td>Number of participants (girls/boys)</td>
</tr>
<tr>
<td>Right</td>
<td>53 (21/32)</td>
</tr>
<tr>
<td>Left</td>
<td>53 (20/33)</td>
</tr>
</tbody>
</table>

Mean chronological age did not differ according to group ($t = .005$, $p = .99$, ns).
(140 × 80 mm), with the long edge oriented vertically and centred with respect to the child’s body; the distance between the graphic space and the eyes of the child was approximately 30 cm. Instructions for drawing were given orally by the experimenter. There was no limit of time for completing the drawing, and children were free to use the colour crayons as they wished. Children completed their drawing in about 5 minutes. Afterwards they were thanked, and invited to discuss about their drawing.

We assessed the horizontal displacement (D) of each individual drawing from the actual centre of the graphic space by (i) measuring the distance (d) in mm from the midpoint of the top of the trunk to the right edge of the graphic space, and (ii) calculating 40 minus d. The resulting D value was negative for a leftward displacement, and positive for a rightward displacement (for a similar procedure see Barrett & Craver-Lemley, 2008; Heller, 1991). When the tree was drawn centred on the page, the resulting D value was zero (null displacement). We also measured drawing size (height in mm) as the vertical distance from the highest to the lowest extremity of the tree drawing (including roots whenever present) (for a similar procedure see Picard & Lebaz, 2010). Barrett and Craver-Lemley (2008) suggested that future studies should consider differences in drawing size and the relationships between size and placement. The coding of the drawings was performed offline by a research assistant who was naïve with respect to the hypotheses underlying the study. A second judge coded offline a subset of the drawings. The resulting inter-judge reliability was better than 95%.

To test whether handedness effects reported by Heller (1991) with person drawing would generalise to tree drawing we performed an independent-sample Student’s t-test contrasting D values between right- and left-handed participants. We also performed one-sample t-tests contrasting the obtained D values to zero for each group separately. To test whether chronological age or drawing size would influence drawing displacement we used analysis of covariance (ANCOVA) to analyse the effect of handedness, controlling for the effects of chronological age (in months) and drawing size (height in mm). We set an alpha level at .05 for all statistical analyses.

Results

Shapiro-Wilk tests revealed that the data distributed normally for each group with opposite handedness (right-handed group: W = .956, p = .06; left-handed group: W = .990, p = .95). Inspection of the distributions indicated that for right-handed children the normal curve peaks at a negative D value, whereas for left-handed children the normal curve peaks close to zero (see Figure 1). Overall, right-handed children demonstrated a leftward bias (M = −3.83 mm leftward of page centre, SD = 5.21) that was significantly greater than that observed in left-handed children (M = −1.36 mm, SD = 6.24),
In right-handed children, leftward bias was significantly different from zero (one-sample $t$-test: $t = -2.21, p < .05$). In the left-handed children, however, the observed $D$ value was not significantly different from zero (one-sample $t$-test: $t = -1.58, p = .12$). Results from the ANCOVA confirmed that there was a significant effect of handedness on drawing displacement, $F(1, 102) = 5.12, p < .05, \eta_p^2 = .05$. They also revealed that drawing displacement did not vary significantly according to chronological age ($p = .41$), or drawing size ($p = .48$). Sex was not a significant factor for variations in drawing displacement ($p = .84$). Finally, Pearson’s product–moment correlation analyses indicated no significant relationships among age in months, drawing displacement, and drawing size ($r$ varying between .06 and .15, all $ps > .12$). It is worth noting that a correlation of almost zero was obtained between size and placement of drawing ($r = .06, p = .53$).

**Comments**

The findings from Experiment 1 with the tree drawing replicated those reported by Heller (1991) with person drawing. Namely we found that right-handed French children drew the tree leftward relative to the centre of the graphic space, whereas their left-handed peers demonstrated no bias. Based on these findings it is possible to argue in concert with Heller and others (Alter, 1989) that the leftward bias observed in right-handers is a reflection of right-hemisphere specialisation in spatial tasks, such as drawing, with the
specialised hemisphere provoking an attentional bias to the (contralateral) left side of space. In this perspective the smaller-in-magnitude and non-significant leftward bias observed in drawings made by the left-handers may be directly linked to the assumption that these children are less lateralised than the right-handed children. However, an alternative explanation of the findings may also be set up. As we have discussed previously, it is possible that drawing displacement is also due to the converging or diverging influence of preferred directionality of graphic movements (biomechanical aspects) and acquired directionality of scanning (reading/writing habits). We designed Experiment 2 to test the possible role of directionality trends on the observed leftward spatial bias.

**EXPERIMENT 2: SPATIAL BIAS IN DRAWING PLACEMENT BY FRENCH AND MOROCCAN CHILDREN**

Experiment 2 tests the possible role of directionality trends by comparing spatial bias in children with opposite directional trends (with regard to reading, writing, and drawing habits). French and Moroccan right-handed children were compared because their scripts have opposite directionality: left-to-right for the French children and right-to-left for the Moroccan children. Also, in both cultural groups script directionality was congruent with drawing directionality. The French right-handed children are known to favour left-to-right directions in their drawing movements (e.g., Picard, 2011; van Sommers, 1984), congruent with their left-to-right reading/writing habits. The Moroccan children are known to use preferentially right-to-left drawing movements (e.g., Nachshon, 1981; Vaid et al., 2002), congruent with their right-to-left reading/writing habits (see also Goodnow, Freidman, Bernbaum, & Lehman, 1973).

**Method**

*Rationale.* The hemispheric specialisation hypothesis predicts a similar leftward bias in drawings made by both cultural groups, irrespective of their directionality trends. By contrast, the directional trends hypothesis predicts opposite patterns of bias in the two cultural groups (leftward bias for French children, rightward bias for Moroccan children). In cases where both right hemispheric activation and directional trends play a role in determining the leftward spatial bias, different patterns of bias could emerge in the two cultural groups, with a possible weaker-in-magnitude leftward bias in Moroccan children whose directional trends may act counter to the cerebral tendencies.
procedure. A total of 128 brain-intact children aged 7 to 11 years took part in Experiment 2. Participants were consistently right-handed (for drawing and writing habits), but they differed on the directionality of their (first) reading/writing habits, and drawing habits: half of them were French children with a left-to-right directional trends; the other half consisted of Moroccan children with right-to-left directional trends (see Table 2). All participants came from middle-class districts of French and Moroccan cities (Montpellier and Fès, respectively), and were recruited from elementary schools (five school levels, from Grade 1 to Grade 5, with approximately 12 children per school level and cultural group). Besides their opposite directional trends, the two cultural groups were comparable on the age at which formal instruction of literacy is introduced at school (6–7 years). Children from the first grade were in the period during which formal learning of written language is operated at school in both countries, whereas those from grade 5 had fully finished their formal learning of written language. Thereby, while children from both cultural groups attended formal education and learning of written language at school, the older children had more reading/writing experience than the youngest children due to their higher school level. Note that we restricted the age range to 7–11 years because this is the crucial period during which formal instruction of the (first) written language is operated at school; the possibility that the children of Experiment 2 were exposed to other written languages (and script directionalities) during this learning period was thus strongly reduced. As in Experiment 1, none of the children was known to suffer from a psychiatric or a psychomotor disorder, and written parental consent was obtained for each participant.

Experiment 2 was carried out in accordance with the Declaration of Helsinki – Sixth Revision (2008). The task and materials were similar to those described in Experiment 1, except that oral verbal instructions for drawing were given in dialectal Arabic language to the children who lived in Morocco, and in French for the children who lived in France. Morocco is the meeting point of Amazighe, Arabic, Muslim, and Western civilisations. There is thus a plurality of national languages: the (oral) dialectal Arabic

<table>
<thead>
<tr>
<th>Cultural group</th>
<th>Number of participants (girls/boys)</th>
<th>Mean age (in months) (SD)</th>
<th>Min–Max for age (in months)</th>
<th>Mean D value (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>French</td>
<td>64 (32/32)</td>
<td>108.00 (13.61)</td>
<td>87–134</td>
<td>−4.20 (7.83)</td>
</tr>
<tr>
<td>Moroccan</td>
<td>64 (31/33)</td>
<td>108.03 (14.76)</td>
<td>82–131</td>
<td>−4.11 (8.09)</td>
</tr>
</tbody>
</table>

Mean chronological age did not differ according to group ($t = −.01, p = .99, \text{ns}$).
language, the Amazighe language, and the standard Arabic language, which coexist with foreign languages such as French, Spanish, English, or German. The standard Arabic language is the official language in Morocco, and serves mainly written communication; it is also used both as the teaching language and as a learned language at school. The dialectal Arabic and the Amazighe languages are mostly used for oral communication and daily life (see Zarhbouch, 2011).

Results

Shapiro-Wilk tests revealed that the data distributed normally for each cultural group with opposite directional trends (French group: $W = .980, p = .39$; Moroccan group: $W = .993, p = .99$). Inspection of the distributions revealed that for both French and Moroccan children the normal curves peaked at negative $D$ values (see Figure 2). Overall, French children demonstrated a leftward bias ($M = -4.20$ mm leftward of page centre, $SD = 7.83$) that was not significantly different from that observed in Moroccan children ($M = -4.11$ mm, $SD = 8.09$), ($t = -.07, p = .94$). In French children, leftward bias was significantly different from zero (one-sample $t$-test: $t = -5.22, p < .001$), as was also the case for Morocco children (one-sample $t$-test: $t = -4.19, p < .001$). Results from the ANCOVA confirmed that there was no significant effect of cultural group on drawing displacement, $F(1, 124) < 1, p = .80$. They also revealed that drawing

![Figure 2](https://via.placeholder.com/150)

**Figure 2.** Frequency histogram showing how French and Moroccan participants distributed across drawing displacement ($D$) values. Negative $D$ values indicate a leftward bias, whereas positive $D$ values indicate a rightward bias.
displacement did not vary significantly according to chronological age \((p = .93)\), or to drawing size \((p = .16)\). Sex was not a significant factor for variations in drawing displacement \((p = .93)\). Finally, Pearson’s product–moment correlation analyses indicated no significant relationships among age in months, drawing displacement, and drawing size \(r\) varying between .01 to .14, all \(ps > .16\). Again, size and placement did not correlate significantly \(r = .12, p = .17\).

**Comments**

The findings from Experiment 2 showed that Moroccan children aged 7 to 11 years demonstrated a leftward bias of comparable magnitude to that observed in their French peers. Interestingly, we found that in both cultural groups, there was no significant change in magnitude bias with increasing age and degree of exposure to the script. These results are against the view that directional trends due to reading/writing habits play a major role in determining spatial bias in drawing placement. Rather, our findings convincingly support the hemispheric specialisation hypothesis which predicted a similar leftward bias in drawings made by both cultural groups, irrespective of their opposite directionality trends.

It should be noted here that a cross-cultural study by Barrett et al. (2002), comparing left-to-right horizontal Korean readers (aged 35 years) with right-to-left vertical Korean readers (aged 65 years), also revealed no effect of script directionality on participants’ tendency to draw objects leftward of the actual centre of the graphic space. However, as stressed by the authors themselves, their results need to be taken with caution due to confounding variables (reading direction was confounded with age, and their older Korean participants had mixed reading exposure). The developmental approach used in our Experiment 2 eliminated these confounding variables, as children from both cultural groups were within the same age range (7–11 years), and their young age prevented them from being exposed to other scripts and mixed reading/writing directions.

**GENERAL DISCUSSION**

Our study was a developmental investigation of spatial bias in the implicit page centring task, taking handedness (Experiment 1) and directional trends (Experiment 2) into account. It was intended to test the concurrent hypotheses of hemispheric activation and directional trends that may account for the leftward spatial bias observed in single drawing placement. In Experiment 1 we replicated Heller’s (1991) finding of a handedness effect on spatial bias in drawing placement, using the draw-a-tree task with a sample of French children and adolescents aged 5–15 years. Right-handed,
but not left-handed, participants demonstrated a leftward displacement in their drawings of the tree, irrespective of their age.

In Experiment 2 we found that children aged 7–11 years from two cultural backgrounds with opposite directional trends (right-to-left versus left-to-right) both placed their drawings of the tree slightly but significantly leftward of page centre. Again, age was not a significant factor of variation of spatial displacement. Taken together, the findings of our study present a clear indication that directionality trends arising from learned cultural habits and motor preferences play little role in determining spatial bias in the implicit page centring task. Rather there may be a cerebral origin for drawing single objects slightly towards the left side of the graphic space.

The finding of a left hemispatial bias in the centring of single objects on a page is congruent with left hemispatial biases observed in explicit spatial computation tasks, such as the line bisection task (Jewell & McCourt, 2000). Interestingly the left hemispatial bias is not unique to humans and human brain organisation, as attested by numerous studies showing that left-side visuospatial biases also occur in nonhuman species in a variety of tasks (e.g., line-bisection task, Regolin, 2006; cancellation task, Diekamp, Regolin, Gunturkun, & Vallortigara, 2005; object localisation task, Regolin, Rugani, Pagni, & Vallortigara, 2005; serial search task, Rugani, Kelly, Szelest, Regolin, & Vallortigara, 2010; for review see also Vallortigara & Rogers, 2005).

The finding of no effect of directional trends on spatial positioning of a single object drawn on a page (our study; see also Barrett et al., 2002) might seem, at least at first sight, in contradiction with findings that directional trends influence spatial orientation of objects drawn in isolation (Kebbe & Vinter, 2013) and spatial positioning of two objects within a scene (Vaid et al., 2011). As we will argue below, spatial positioning is independent of spatial orientation, and the drawing of a single object does not call for the same mechanisms as the drawing of multiple objects within a scene.

First, in cases where a single object is drawn on a page, this object can be drawn in several orientations (e.g., back, front, left, or right profile) irrespective of its spatial location relative to page centre. Drawing a single object involves putting in a sequence a series of poly-semantic graphic units that are ordered following semantic and geometric constraints (Picard & Vinter, 2005; van Sommers, 1984). Directional trends may affect the ongoing process of drawing a single object and thereby the final orientation of the drawing, but not its final position in space. On the one hand, the region of space where the drawing process will take place is likely slightly biased leftward of actual page centre, due to the spatial nature of the task to be performed and the preferential activation of the right hemisphere (see Barrett & Craver-Lemley, 2008; Barrett et al., 2002; Heller, 1991). On the other hand, spatial orientation of side-view objects mostly depends on acquired directional trends shaped by both biomechanical factors and...
cultural factors relative to script directionality. As shown by van Sommers (1984), drawers usually start by depicting the most important feature of an object (e.g., the head rather than the tail when drawing an animal) and progress either right-to-left or left-to-right depending on their preferred directional movements. These preferential directions for drawing are acquired and determined by a smooth and economical exploitation of the biomechanics of the hand used for drawing (which may explain emerging differences in spatial orientation between right- and left-handers during childhood; see Picard, 2011), and by extensive exposure to culture-dependent script directionality that reinforces or supersedes the motor tendencies (which may explain emerging differences in spatial orientation between left-to-right and right-to-left readers/writers during childhood; see Kebbe & Vinter, 2013).

Second, when plural objects are drawn within a graphic space, and are assumed to entertain precise relationships (e.g., one object is in front of another, or one object pushes another), the end product denotes a graphic scene that has a story to tell to an external observer. The event illustration task is no more solely an implicit spatial computation task but it encompasses linguistic demands that may increase the left hemisphere activation (see Altmann et al., 2006). Drawing is a symbolic representational system and it can be regarded as a (nonverbal/graphic) language (Baldy, 2011; Lange-Küttner & Vinter, 2008). A graphic scene is constructed step by step like a sentence which may likely conform to the acquired directional habits of the cultural script as well as to the graphic conventions for depth depiction (Freeman, Eiser, & Sayers, 1977). Directional trends due to acquired reading/writing habits may affect the ongoing process of putting in sequence a series of individual figures that will compose the final scene. Thereby cultures with opposite script directionality may demonstrate opposite spatial-syntactic biases in picture illustration tasks (Dobel, Diesendruck, & Bölte, 2007; Maass & Russo, 2003; Vaid et al., 2011). In scene denotation, unlike in single drawing, the graphic space has become a more complex reading space, where individual positions of graphic objects can be meaningful on their own.

To conclude, drawing is a complex activity involving spatial and linguistic components depending on the specific task demands. Within the range of possible drawing tasks, that of drawing a single object on a page (a tree, a house, a person) can be used successfully as a means to examine implicit visuo-spatial bias in graphomotor behaviour by children and adults. The left hemispatial bias observed in our study is likely to occur in real-world settings, and may thus have implications for a variety of naturalistic settings, including educational and psychiatric settings. In psychiatric settings, psychological tests involving the HTP test (House-Tree-Person test; Buck, 1948) should be conducted considering that drawings with a leftward
deviation from actual page centre are not necessarily a reflection of the participant’s tendency to anchor in the past: rather they are a behavioural product of the nature of human brain organisation.

REFERENCES


