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Impact of manual preference on directionality in children's drawings

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The effects of handedness on directionality in drawing are already well documented in the literature, at least as far as adults are concerned. The present study investigates the impact of manual preference on directionality as seen in the drawing product and drawing process, from a developmental point of view. A total of 120 children aged 5 to 9, both right and left-handed drawers, volunteered for the study. Children were asked to draw twice from memory a set of six common objects. Results indicate that directionality in drawing product varies significantly according to manual preference in the 9-year-old children, but not in the younger age groups. The concomitant increase between 7 and 9 years of age in the use of preferred stroke directions and the impact of manual preference in the drawing process suggests that biomechanical factors might play an important role in behavioural asymmetries in drawing.

Keywords: Drawing; Children; Manual preference; Directionality.

Most objects are drawn in a preferred direction that may vary according to the hand involved in the drawing activity. The effects of handedness on directionality in the drawing product have already been well documented in the literature, at least as far as adults are concerned (see Alter, 1989; De Agostini & Chokron, 2002; Karev, 1999; Taguchi & Noma, 2005; van Sommers, 1984; Viggiano & Vannucci, 2002). For instance, Viggiano and Vannucci (2002) showed that handedness had an effect on the directionality of drawing objects from two main categories, vehicles and animals. Objects from these categories tended to be depicted following a leftward-facing direction by right-handed drawers (e.g., a dog in a left profile), whereas left-handed drawers tended to favour the reverse direction (rightward facing). Studies from van Sommers (1984) have also shown that, in adults, the drawing of graspable objects (e.g., cups, scissors) varied in directionality according to handedness. Objects from this category tended to be drawn with

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their handle turned to a direction consistent with the dominant hand, as if they were affording action (De'Sperati & Stucchi, 1997).

The impact of handedness on directionality in drawing has been assumed to reflect hemisphere-specific mechanisms in the adult brain (Alter, 1989; Banich, Heller, & Levy, 1989; Bryden, 1988; Dreman, 1974; Karev, 1999), which may account for the different left-to-right or right-to-left visuo-spatial and visuo-motor strategies adopted respectively by the right- and left-handers. According to Kinsbourne (1970), unilateral activation of a hemisphere caused an attentional bias to the contralateral hemisphere. Spatial tasks such as drawing are expected to activate the right hemisphere more than the left, leading to a bias of attention to the left hemispace. The leftward bias is commonly explained as a preferential right hemisphere activation relative to the spatial nature of the task. Handedness differences in spatial tasks would depend on the degree of functional hemispheric asymmetry, which is stronger in right- than in left-handed participants.

Besides a cerebral account of directionality, different authors have pointed to the role of motor or biomechanical factors (Taguchi & Noma, 2005; Vaid, Singh, Sakhuja, & Gupta, 2002; van Sommers, 1984). According to van Sommers (1984), for instance, drawers preferentially produce tensor movements outward from the body rather than flexor inward movements to the extent that the former are smoother, more rapid, and more accurate than the latter. Adults' tendency to begin the drawing of an object with a key feature (e.g., the head of the dog rather than its back) combined with their tendency to generate outward movements may explain why right-handed drawers tend to depict moving objects in a leftward direction whereas left-handed drawers are more prone to draw them in the opposite direction.

Prior reading and writing habits may act to reinforce or conversely to refrain the influence of biomechanical factors on directionality in drawing, at least to a certain extent (Chokron & De Agostini, 2000; Vaid, 1995, 1998). Therefore biomechanical and cultural explanations of directionality in drawing might pose a challenge to hemisphere-based interpretations of behavioural asymmetries in drawing. The present study was designed to investigate further the role of biomechanical factors on directionality in drawing, using a developmental approach.

In the early stages of drawing development, young children's drawing movements are not as structured, economical, or as smooth as those of adults. Up until age 7 children do not fully adhere to the rules of the so-called "grammar of action" (Goodnow & Levine, 1973), which specify preferred starting points and stroke directions for drawing (Scheirs, 1990; van Sommers, 1984). In adults, preferred stroke directions differ among right- and left-handers, with the stroke directions favoured by right-handers tending to be inverse to those of left-handers (van Sommers, 1984). It seems that children need time to learn and discover the full resources of their motor-effector system, in such a way that they gradually begin to use more smooth and efficient movements for their drawing activities. These developmental changes in the motor components of the drawing activity offer an interesting avenue in which to test the hypothesis of a biomechanical basis for directionality in the drawing product. Indeed, if motor components play a key role in directionality in drawing, we may predict that the effect of manual preference on directionality in drawing product would emerge once children are sufficiently able to exploit the potential of their motor system; that is to say, after age 7 (see Goodnow & Levine, 1973). In line with a biomechanical hypothesis, the impact of manual preference on directionality in the drawing product should occur concurrently with a stronger adherence to privileged movement directions in the drawing process.

We tested these predictions by analysing representational drawings produced by 5-, 7-, and 9-year-old children who either had a right or a left hand manual preference. We conjointly measured directionality in drawing product (tendency to produce left-directed drawings) and directionality in the drawing process, distinguishing between directionality at the figure level (tendency to use a left-to-right sequencing of the graphic components) and at the stroke level (tendency to use preferred directions for the initialisation of each individual stroke). Note that the measured tendencies were all expected to characterise drawing behaviour of individuals with a right manual preference and left to right reading habits.

METHOD

Participants

A total of 120 French children were observed. They were divided into three age groups of 40 children each: 5 years ($M = 5$ years 6 months, $SD = 4$ months), 7 years ($M = 7$ years 5 months, $SD = 4$ months), and 9 years ($M = 9$ years 7 months, $SD = 5$ months). All had a left-to-right reading habit, but the older age group had more reading experience than the other age groups due to their higher school level. In each age group children were further divided into two groups of right- versus left-handers (20 children per group), under the constraint that they be distributed equally according to gender. Manual preference was assessed by an eight-item questionnaire developed by De Agostini and Dellatolas (1988). This test was chosen because of its suitability for young children. It involves a series of actions (e.g., brushing teeth, cutting with a knife), for which a participant could use the right hand only, the left hand only, or both hands. Each item was scored as “1” for right, “2” for right plus left, and “3” for left. Manual preference was scored from 8 (the strongest right manual preference) to 24 (the strongest left manual preference). Participants who had scores ranging from 8–12 were classified as right-handed; those who had scores ranging from 20–24 were classified as left-handed. Note that all left-handed children wrote with their left hand.

Stimuli and procedure

Children were asked to draw twice from memory, with their preferred hand, a set of six common objects. The objects were a walking dog, a facial profile, a bicycle, a truck, a cup, and a jug. This set of objects was similar to that used by Alter (1989) except that the aeroplane item was replaced with the cup. So our set included two exemplars each from the animate, vehicle, and self-centred tool categories. Because it is rather unusual for 5-year-old children to draw faces in a profile view, the experimenter explained what a profile view meant for this item. In a small number of cases ($n = 6$ out of 40), it was necessary to ask children from the youngest age group to draw this item again so that it conformed to a profile view. Children were asked to draw the objects twice in order to permit the assessment of intra-individual consistency in directionality. When the experimenter named an object, children produced two drawings of the item in immediate succession, one on each side of a white paper sheet (size: 10×14 cm). The presentation order of names of objects was random for each child. There was no time limit for the drawing task, which did not exceed on average 10 minutes per child. The full sequence of the drawing movements (i.e., starting points, individual movement directions, and order of production of the drawing movements; see example in Figure 1A) was recorded during the task by an experimenter specifically trained for this activity. In order to enable full visibility of children's drawing activity, the experimenter sat at the left side (vs right side) of right-handed (vs left-handed) children.

Coding directionality in drawing product

Two judges coded the direction (left or right) of each graphic product. They were naïve with respect to the aim and hypotheses of the study. Inter-judge agreement was 100%. The dependent variable was the frequency of leftward-facing drawings taken per participant across all 12 drawings. Leftward-facing (vs rightward-facing) drawings were typically expected from the right-handed (vs left-handed) drawers. Figure 1B provides samples of leftward facing drawings.

Coding directionality in drawing process

Directionality at the figure level. Two judges coded the predominant direction (from left to right or from right to left) of the drawings according to the order of the graphic components of each object (see Vaid et al., 2002,

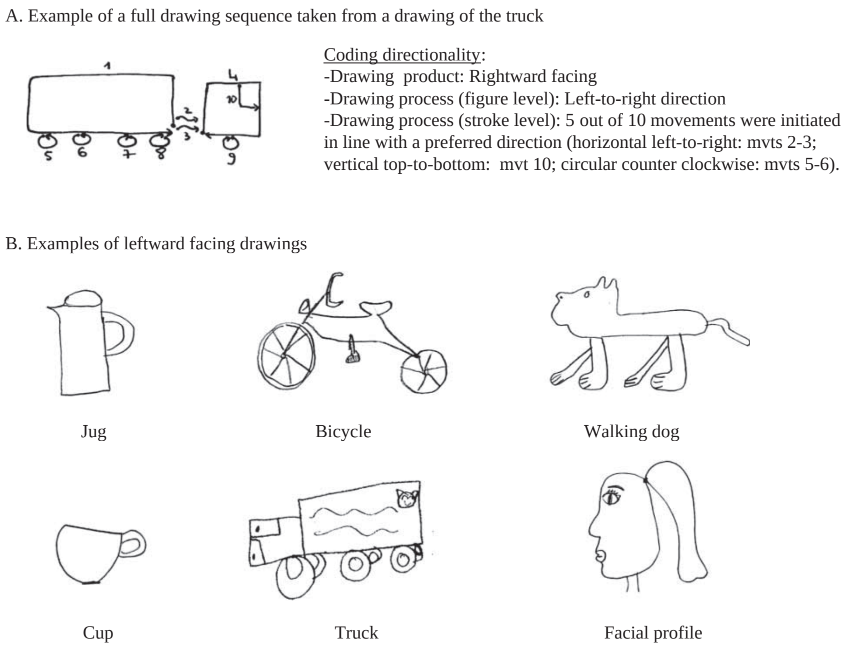

Figure 1. Example of a full drawing sequence taken from a drawing of the truck (A), and samples of leftward-facing drawings (B).

for a similar analysis with adults; see also example of coding in Figure 1A). The dependent variable was the frequency of left-to-right production taken per participant across all 12 drawings. Left-to-right (vs right-to-left) direction was typically expected from the right-handed (vs left-handed) drawers.

Directionality at the stroke level. Two judges coded whether the starting direction of each drawing movement followed a left-to-right direction (for horizontal strokes), a top-to-bottom direction (for vertical strokes), a 1- to 7-pm direction (for oblique strokes), and a counter-clockwise direction (for circular strokes) (see example of coding in Figure 1A). The dependent variable was the number of movements for which the starting direction adhered to these preferred stroke directions, divided by the total number of movements in the drawing. The scores ranged from 0 to 1, with 1 indicating that all drawing movements were initiated in line with a preferred direction. The scores reflected a range taken per participant across all 12 drawings. These preferred stroke directions were typically expected from the right-handed drawers. By contrast, left-handed drawers were expected to display inverse stroke directions (i.e., right-to-left direction for horizontal stroke, bottom-to-top direction for vertical strokes, 5- to 11-pm direction for oblique strokes, and clockwise direction for circular stroke). Inter-judge agreement for the coding of directionality in drawing process was obtained in at least 95% of the cases. Disagreements were settled by discussion before data analysis.

RESULTS

Each dependent variable was submitted to a 2 (Manual Preference) $\times$ 3 (Age) analysis of variance with manual preference and age as between-participants factors. We used an alpha level of .05 for all our statistical analyses. Preliminary analyses did not reveal a significant effect of gender. As far as directionality in drawing product is concerned, results showed an effect of manual preference, $F(1, 113) = 15.16$, $MSE = 1.16$, $p < .01$, $\eta_p^2 = .12$, and an interaction effect between age and manual preference, $F(2, 113) = 3.85$, $MSE = 0.29$, $p < .05$, $\eta_p^2 = .06$, on the frequency of leftward-facing drawings. Age was not a significant factor, $F(2, 113) = 2.13$, $MSE = 0.16$. Post hoc analyses on the interaction (Tukey test) indicated that the impact of manual preference on directionality in drawing product occurred at age 9 only ($p < .01$) and not among younger age groups. Within right handers, the frequency of leftward facing drawings was higher at age 9 than at age 7 ($p < .05$). As results from Figure 2A indicate, at age 9 but not at younger ages, children with a right manual preference produced significantly more leftward-facing drawings ($M = 70\%$) than children with a left manual preference ($M = 30\%$). This mirror trend echoes that known for adult drawers. The absence of a laterality effect in the younger age groups cannot be attributed to inconsistency in children's orientation of drawings products.

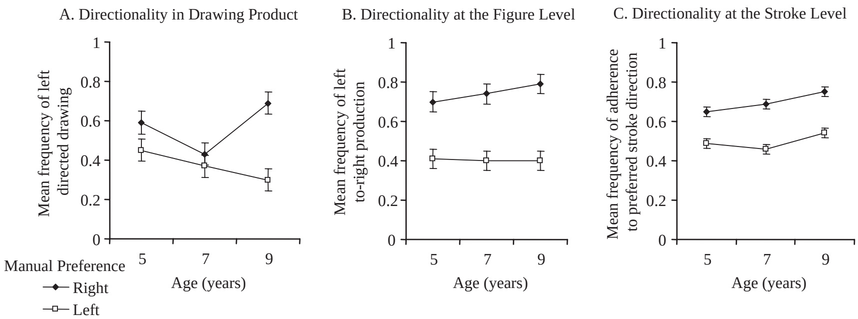

Figure 2. Results for directionality in drawing product (A: mean frequency of leftward-facing drawing), for directionality at the figure level (B: mean frequency of left-to-right production), and for directionality at the stroke level (C: mean frequency of adherence to preferred stroke direction) as a function of age and manual preference.

Regardless of the age group, participants were strongly conservative in the directionality of their products across repeated trials at the intra-individual level ($M = 80\%$ of constant directionality). They demonstrated minor variations in their tendency to produce leftward-facing drawings following the nature of the drawn object. Details about the percentage of leftward-facing drawings produced for each object are provided in Table 1.

Concerning directionality at the figure level, results showed an effect of manual preference, $F(1, 113) = 68.40$, $MSE = 3.50$, $p < .001$, $\eta_p^2 = .38$, but no effect of age, $F(2, 113) = 0.29$, $MSE = 0.01$, and no interaction, $F(2, 113) = 0.53$, $MSE = 0.02$, on the frequency of left-to-right progression. Results from Figure 2B show that children's tendency to follow a left-to-right progression at the figure level was higher for right ($M = 74\%$) than for left ($M = 40\%$) manual preference. It is worth noting here that, in line with van Sommers' observation (1984), drawers mostly started their drawing with the more important feature (e.g., the head of the dog, the body of the cup, the front of the truck), regardless of their age or manual preference.

As far as directionality at the stroke level is concerned, results showed an effect of manual preference, $F(1, 113) = 98.82$, $MSE = 1.19$, $p < .001$, $\eta_p^2 = .47$, and of age, $F(2, 113) = 5.28$, $MSE = 0.06$, $p < .01$, $\eta_p^2 = .08$, on the frequency of adherence to preferred stroke directions. There was no interaction, $F(2, 113) = 1.08$, $MSE = 0.01$. As results from Figure 2C indicate, children with a right manual preference demonstrated a larger tendency to conform to preferred stroke directions ($M = 70\%$) as compared to children with a left manual preference ($M = 50\%$). Post hoc analyses on the age effect (Tukey test) revealed a significant increase between 7 ($M = 58\%$) and 9 years of age ($M = 64\%$) in the use of preferred stroke directions ($p < .05$). Thus the emergence of an impact of manual preference on directionality in drawing product at age 9 was concomitant with an increase in the use of preferred stroke directions at the process level.

TABLE 1
Percentage of leftward facing drawings of each object by age group and manual preference

	5 years		*7 years*		*9 years*	
	RH	*LH*	*RH*	*LH*	*RH*	*LH*
Walking dog	50; 55	30; 55	35; 40	25; 35	55; 55	25; 15
Facial profile	80; 65	50; 30	40; 50	40; 50	65; 70	45; 40
Bicycle	40; 40	30; 45	45; 40	35; 40	70; 75	20; 15
Truck	55; 55	35; 40	30; 40	40; 30	65; 50	30; 25
Jug	55; 50	40; 45	55; 45	35; 40	80; 75	35; 30
Cup	80; 85	70; 75	55; 45	40; 35	90; 85	35; 30

% for first drawing; % for second drawing.

Significant correlations were obtained between measures of directionality in drawing product and measures of directionality at the stroke level at age 9 (Spearman correlation, $r = .44$, $p < .01$) but not in the younger age groups. As observed for directionality in drawing product, a large consistency (> 80%) characterised directionality in the drawing process at the intra-individual level across repeated drawings, both at the figure and stroke levels.

DISCUSSION

Findings from the present study show that manual preference impacts directionality in drawing product at age 9, but not at younger ages. The impact observed at age 9 reveals a behavioural asymmetry that is similar to that already known in adult drawers (e.g., Viggiano & Vanucci, 2002). Previous developmental studies have emphasised changes with age in directionality of children's drawing products (e.g., De Agostini & Chokron, 2002; Picard & Durand, 2005; Taguchi & Noma, 2005), with young children tending to digress from the type of directions typically employed by adult drawers. Our study is the first to highlight a late emergence of an interaction between manual laterality and directionality in drawing product during childhood. This age-related interaction may be related to changes in manual and cerebral lateralisation processes during childhood (Annett, 1970; Gesell & Ames, 1947). On the other hand, results from our analyses of the underlying drawing processes suggest that biomechanical factors and writing/reading habits may also play a key role in directionality in drawing product according to children's manual preference.

Analyses carried out at the process level indicate that as early as 5 years of age manual preference modulates directionality of children's drawing movements, both at the figure and stroke levels. At the figure level children with a right manual preference favour a left-to-right sequencing in their drawing process, whereas children with a left manual preference tend to favour a reverse direction for sequencing (right-to-left). This behavioural asymmetry in the proximal (i.e., global) control of the drawing process testifies to a preferential use of tensor outward movements in child drawers similar to that already observed in adult drawers (Vaid et al., 2002; van Sommers, 1984). At a deeper (stroke) level, our results also reveal a differential use of local movement directions according to manual preference (Scheirs, 1990). Interestingly, we observed an increase between 7 and 9 years of age in children's adherence to preferred stroke directions regardless of their manual preference. In our view, this stronger adherence to preferred stroke directions reflects a better exploitation of the motor-effector system in the distal (i.e., local, fine) control of graphic movement with age.

We suggest that the emergence of an interaction between manual laterality and directionality in drawing product at age 9 may be the result of an increase in the distal control of graphic movements, as attested by the stronger use of preferred stroke directions in the underlying drawing process. Smoother and more accurate control for fine drawing movements by 9-year-old children may lead them to spontaneously draw objects in specific directions with the use of their dominant hand. However, the fact that our participants were only tested with their dominant hand made it hard to tease apart the influence of handedness per se from hand movement bias associated with right vs left hand use. Therefore the results reported in this study need to be confirmed through examining additional drawings produced with the non-dominant hand.

It is likely that reading and writing directionality acted as an additional influence that reinforced children's biases in movement direction (Chokron & DeAgostini, 2000). Namely, the significant group differences found between right- and left-handers only in the older age group (in whom reading and writing habits were stronger) suggest that cultural habits have interacted with handedness and the associated biases in movement direction. In addition, right-handers might have demonstrated a stronger leftward-facing bias and left-to-right movements because outward movements were working in concert with a left-to-right writing/reading direction. By contrast, in left-handers the two were working against each other, hence weakening the effect. In other words, left-to-right reading habits coupled with use of the right hand might have led to a stronger leftward-facing bias than left-to-right habits coupled with use of the left hand. However, the acquisition of left-to-right writing and reading habits cannot itself fully account for directionality in drawing. Indeed, at the figure level, both right- and left-handed children tended to produce outward movements, which led them to draw the graphic components either in a left-to-right or right-to-left direction regardless of their age. Thus, for left-handers biomechanical principles may have superseded cultural influences on directionality (see Vaid et al., 2002).

To conclude, our study points to the role of biomechanical factors in the emergence of behavioural asymmetry difference in drawings made by right- and left-handers. As we have discussed, biomechanical influences interacted with those of writing and reading habits, but cultural factors could not entirely explain our findings. Biomechanical factors present a convincing account of asymmetries in drawing product and process that may not be incompatible with explanations invoking hemisphere-specific mechanisms. Indeed, the developmental changes observed between age 5 and 9 in adherence to preferred stroke directions may testify to the influence of personal training in the drawing movements, but in all probability they may also result from a normal maturation process. In other words, a stronger adherence to preferred stroke directions may contribute to the reinforcement of hemispheric specialisation and, at the same time, it may be a direct reflection of it.

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