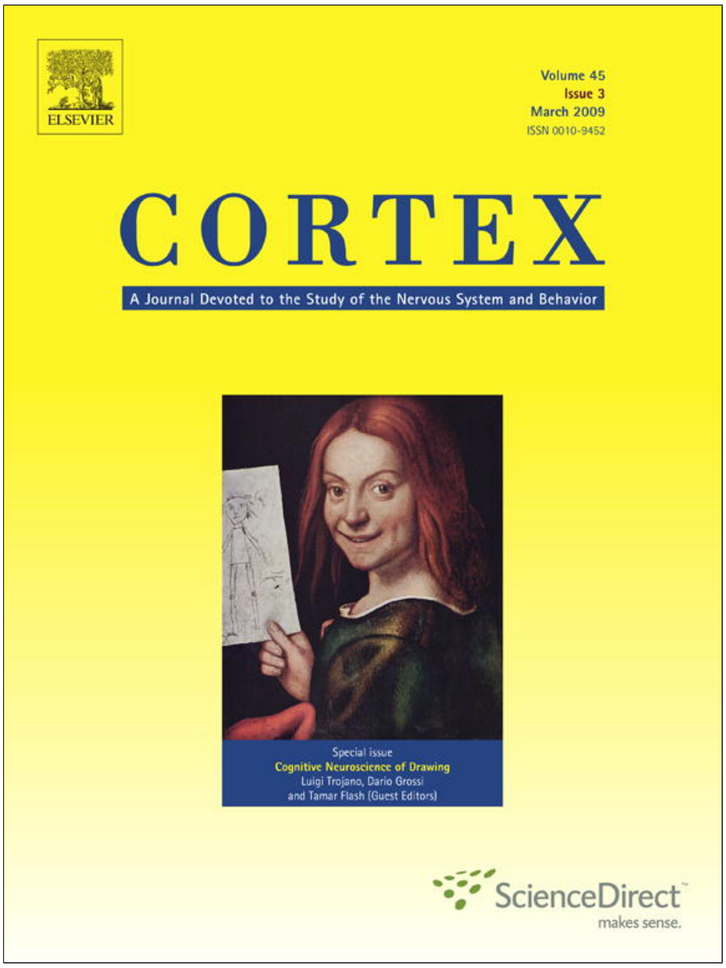
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Animal magnetism: Evidence for an attraction account of closing-in behaviour in pre-school children

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ABSTRACT

Many pre-school children show 'Closing-in behaviour' (CIB) in graphic copying, placing their copy excessively close to, or even on top of the original. This behaviour can also be observed in patients with dementia, though it is unclear whether the superficial similarities between CIB in development and dementia reflect common underlying mechanisms. Two main hypotheses have been proposed to account for CIB: the compensation hypothesis considers CIB as a strategic adaptation to underlying deficits in visuospatial and/or memory functions; the attraction hypothesis proposes that CIB is a primitive default behaviour in which the acting hand is drawn towards the focus of visual attention. The present study tested between these hypotheses in a group of 15 pre-school children. The children performed a simple straight-line drawing task whilst naming line drawings of animals printed at the top or bottom of the sheet. The drawn lines veered reliably towards the named animals, mimicking CIB in copying tasks. This pattern is not predicted by the compensation hypothesis, but is consistent with the attraction account. We suggest that this default attraction may emerge in children with insufficiently developed attentional and/or executive control.

1. Introduction

When young (pre-school) children are asked to copy drawings, a significant proportion will construct their copy excessively close to, or even on top of the original model, as if drawn magnetically to that which already exists on the page (Prudhommeau, 1947; Wallon and Lurçat, 1957). This normal aspect of graphic development closely resembles a pathological phenomenon seen in adult neurology, termed 'closing-in behaviour' (CIB; after Mayer-Gross, 1935) and classed as a form of constructional apraxia (e.g., Critchley, 1953; Grossi and Trojano, 2001). The relatively small, but surprisingly diverse literature on CIB indicates that attraction towards a model can emerge across a variety of copying tasks (e.g., drawing, writing, 3D construction, gesture imitation) and with wide-ranging aetiologies (dementia, cerebral stroke, carbon monoxide poisoning, corticobasal degeneration, encephalitis, epilepsy) (De Ajuriaguerra et al., 1949; Critchley, 1953; De Renzi, 1959; Denny-Brown, 1958; Kwon et al., 2002; Lhermitte and Mouzon, 1941; Mayer-Gross, 1935; Muncie, 1938; Stengel and Vienna, 1944; Vereecken, 1958).

Mendilaharsu et al. (1970) were the first to make use of the category of CIB in studying children. Copying of a geometric figure was assessed in 386 children, aged between two and

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seven years. Three main stages in the evolution of performance were identified: occupation of the model (scrawling over the model), utilisation of the model (drawing connected to or bounding the model), and separation of the copy from the model. Scrawling over the model was universal in children under two-and-a-half years, and declined in incidence thereafter, disappearing by the age of four, whilst utilisation of the model had its peak incidence at around three-and-a-half years of age. By the middle of the fifth year, all children had achieved separation of the copy from the model. The parallel with adult CIB, drawn by these authors, implies that its appearance in association with neuropathology might represent regression to more primitive stages of graphic development (see also De Ajuriaguerra et al., 1960).

A similar developmental trajectory was described by Gainotti (1972), who assessed 118 children aged from two to six years on the graphic copying battery of Arrigoni and De Renzi (1964). The typology employed by Gainotti was conceptually close to that of Mendilaharsu et al. (1970), but distinguished four (rather than two) sub-types of CIB: scrawling on the model; overlapping or bounding the model; extending lines from the model to the surrounding space; copying near or adherent to the model. The findings were broadly consistent with the patterns reported by Mendilaharsu et al. (1970): scrawling on the model was common (75%) in two-year olds, decreasingly frequent in three- (35.5%) and four-year olds (6%), and absent by the age of five, whilst connected, overlapping or bounded copies were most frequent in the three-year old group (25.8%, collapsed across Gainotti's second and third sub-types). The fourth, 'near or adherent', subtype was first observed in three-year olds (6.5%), had its highest incidence in four-year olds (12.1%), and was observed occasionally amongst five-year-old children (7.7%).

A particularly interesting aspect of Gainotti's (1972) study was that the children were tested alongside cohorts of focally brain-damaged patients ($n = 200$, unselected for lesion site) and patients with dementia ($n = 132$). The overall incidence of CIB in the focally brain-damaged group was relatively low (7.5%), but incidence increased with progression of dementia through mild (6%), moderate (42%) and severe (61%). Moreover, the progression of CIB with dementia severity showed a striking reversal of the developmental course in children, with mainly near-or-adherent copying in mild dementia progressing to a severe end-state of scrawling on the model. These observations are consistent with the idea that adult CIB reflects the re-emergence of a primitive pattern, and suggest that similar cognitive factors may underlie the phenomenon in healthy children and brain-damaged adults.

Two primary classes of hypothesis have been held to account for CIB in brain-damaged adults. Some authors have suggested that CIB arises as a strategic attempt to compensate for insufficient visuospatial or working memory resources (e.g., Muncie, 1938; Lee et al., 2004). We refer to this general idea as the 'compensation' hypothesis, according to which the distance between the copy and the model is reduced in order to lighten the visuospatial and/or working memory load imposed by the task. An alternative suggestion is that CIB is a primitive, 'default' behaviour in which the acting hand is drawn towards the focus of visual attention (the model) (De Ajuriaguerra et al., 1960; Gainotti, 1972; Kwon et al., 2002). The details of this account will be considered in later discussion, but the basic proposal is crucially distinct from that of the compensation hypothesis. According to the compensation hypothesis, CIB is a functionally adaptive strategy to aid copying performance; according to the attraction hypothesis, CIB is non-functional, arising merely from the failure to inhibit a default attraction to the focus of visual attention.

In the present paper, we report an experiment designed to test between these two hypotheses in a group of 15 pre-school children, using a straight-line drawing task in conjunction with a visual animal-naming task. The compensation hypothesis predicts that CIB should be specific to situations, such as copying, in which manual performance could benefit from information available elsewhere. By contrast, the attraction hypothesis predicts that manual performance in pre-school children should tend to migrate towards any sufficiently attention-demanding visual stimulus, regardless of its relevance to the manual task. Our data demonstrate that drawing in children is attracted towards the focus of attention defined by an *unrelated* visual discrimination. This result shows that CIB in children is not specific to copying tasks, and provides clear evidence for the attraction hypothesis over compensation accounts. In discussing these findings, we consider the relationship between CIB in development and dementia, and the cognitive factors that might underlie the release of a primitive manual attraction towards the focus of visual attention.

2. Methods

2.1. *Sample*

Fifteen children (10 females and five males) were tested at a day nursery. The age range of our sample was 4.0–5.8 years old (mean age 4.2 years, SD .41). The children were tested in the presence of nursery staff. The tests were presented as a 'game' that the children were invited to play with the examiner. In total, the testing took about 30 min per child. This study received ethical approval from the Ethics Committee of the School of Philosophy, Psychology and Language Sciences, University of Edinburgh. The agreement of the legal representatives of the children was obtained before children were invited to participate.

2.2. *Preliminary graphic copying tasks*

As part of a concurrent study, all of the children performed some preliminary graphic copying tasks. These tasks will be used to characterise graphic copying abilities in the present sample, though the data are drawn from a larger dataset (Ambron et al., 2007), the full analysis of which will be published elsewhere.

We asked the children to copy nine geometrical pictures, varying in complexity (simple, medium, complex). The simple stimuli were a square, a triangle and a circle; the medium-complexity stimuli were overlapped pairs of geometrical figures (overlapped squares, ellipses and triangles); the complex stimuli depicted three-dimensional figures (cube, cylinder and pyramid). Each stimulus was 40 × 40 mm in extent and presented in the centre of the left half of an A4 sheet, in landscape orientation. Children were asked to copy each figure, without specific instructions regarding positioning of the copy, and without time constraints.

For each picture, the accuracy of the copy was rated on a scale from 0 to 2, according to the following descriptors.

0: The copy is unrecognisable.
1: The copy is not accurate, but at least some parts of it are recognisable.
2: The copy is well executed, with no gross distortions of scale.

Additionally, CIB was rated on a 0–4 scale, according to the following descriptors.

0: The copy wholly overlaps the model.
1: The copy partially overlaps the model.
2: The copy touches the edge of model in one or more points.
3: The copy encroaches on the model (<10 mm shortest distance).
4: The copy is well separated from the model (>10 mm shortest distance).

In order to further assess CIB, we asked each child to copy a figure adapted from Luria (1966), consisting of five square, five triangular and five pentagonal elements in rotating sequence along a straight line (see Fig. 1). Similar stimuli have been used for the assessment of CIB in patients with Alzheimer's disease (Lee et al., 2004). Each element was 10 mm long and 10 mm high, and the line connecting the elements was 5 mm long. We presented a sheet of A4 paper in landscape orientation with the Luria figure along the top of the sheet, 30 mm from the top edge, and a 4 mm diameter black dot, 50 mm below the model and 25 mm from the left edge of the page. The instruction was to copy the picture, starting with the pen on the black dot. The previously stated descriptors for copy quality and CIB were used to rate each child's performance on this copying task.

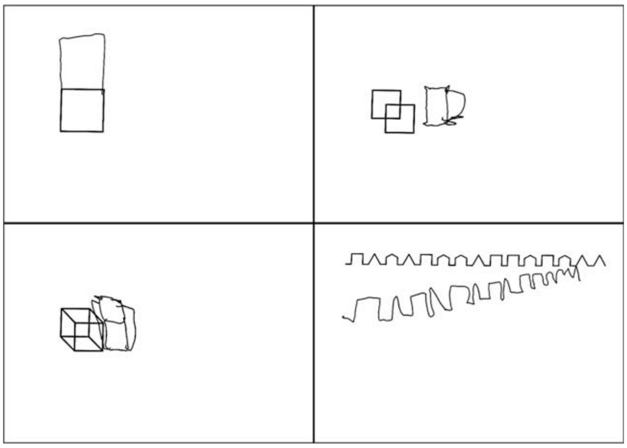

Fig. 1 – Selected examples of CIB for simple (upper left), medium (upper right) and complex (lower left) geometric figures, and for the Luria figure (lower right). These examples illustrate CIB scores of 3 (encroachment, upper right), 2 (contact, upper left and lower right), and 1 (partial overlap, lower left). The pattern of migration towards the Luria figure from the starting point is typical of CIB in this task. No examples of CIB scoring zero (complete overlap) were observed in any child. Note that CIB can be observed in the context of relatively good accuracy of reproduction.

To assess the reliability of the above scales, all 150 drawings were scored independently by two raters. Identical accuracy scores were awarded on 111 trials (74%), and the magnitude of the inter-rater discrepancy never exceeded one point (Rater 1 awarded the higher score for 19 drawings and Rater 2 awarded the higher score for 20 drawings). The inter-rater correspondence was even closer for the CIB scale, with identical scores awarded on 136 trials (91%); again, the magnitude of the inter-rater discrepancy never exceeded one point (the two raters awarded the higher score for seven drawings each). For each drawing, for each scale, the final score awarded was the average of the two raters' scores. For each child, for each scale, an average score was then calculated across the three figures at each level of complexity (simple, medium, complex).

Across the group, copy accuracy decreased as stimulus complexity increased (simple figures: median 1.2, IQR .7–1.3, range .3–2.0; medium figures: median .5, IQR .3–.8, range .0–1.7; complex figures: median .0, IQR .0–.3, range .0–.7). A Friedman test found the effect of stimulus complexity on copy accuracy to be significant (χ^2 (2) = 12.62, $p < .005$). Median copy accuracy for the Luria figure was .5 (IQR .0–1.0, range .0–2.0).

A tendency towards more extreme CIB scores with increasing stimulus complexity was observed (simple figures: median 4.0, IQR 3.7–4.0, range 1.2–4.0; medium figures: median 4, IQR 2.7–4.0, range 1.7–4.0; complex figures: median 3.7, IQR 2.5–4.0, range 1.67–4.0), though a Friedman test was not significant ($\chi^2(2) = 4.1$, $p = .13$). However, this null result does not necessarily imply that stimulus complexity does not influence CIB, since the analysis of the full dataset from which these data are drawn does reveal a significant worsening of CIB with stimulus complexity (Ambron et al., 2007). The median CIB score for the Luria figure was 4.0 (IQR 3.0–4.0, range 1.0–4.0), with one instance of partial overlap, one of contact and four instances of migration to within 10 mm of the model. A further two children produced copies that migrated markedly towards the model, though not passing the 10 mm proximity threshold required for classification with CIB according to our scale.

In summary, as would be expected for children in this age range (e.g., Gainotti, 1972; Mendilaharsu et al., 1970), graphic copying was somewhat inaccurate and copies tended to be placed close to the model. Individually, some relatively extreme examples of CIB (partial overlap) were observed, though no instances of complete overlap. Selected examples of CIB, associated both with relatively good and relatively poor copying accuracy are shown in Fig. 1. These patterns suggest that CIB may, to some degree, be separable from constructional abilities *per se*.

3. Experimental task

3.1. *Preliminary single tasks*

Initially, we asked the children simply to copy straight black horizontal lines presented in landscape orientation. Each line was 232 mm long and 3 mm thick, and presented 25 mm from the top or bottom edge of the paper (see Fig. 2). A 4 mm diameter back dot was centred vertically 25 mm from the left edge of the page. The instruction was to copy the line from left to right, keeping as straight as possible, starting with the pen on the black dot. Each child performed four trials, with model position manipulated according to an ABBA schedule, starting with the line at the top.

In this task, CIB was quantified as the average deviation of the drawn line from the horizontal. This was estimated by measuring the vertical coordinates of the line at 10 mm to the right of the start position and at successive rightward increments of 10 mm, until the right hand edge of the paper was reached or the drawn line was no longer present, and averaging these. Deviations towards the top of the sheet were signed positively and deviations towards the bottom of the sheet were signed negatively, with the zero-level defined by the vertical coordinate of the start position.

In a separate task, we asked each child to name some line drawings of animals (dog, cat, lion, snake, sheep, cow, spider, monkey, rabbit and rooster). Each drawing was 20 mm high, printed in black on white. All children were able to recognise and name these animals satisfactorily, suggesting that this would constitute a suitably straightforward visual sub-task for the experiment to follow.

3.2. *Experimental dual-task*

In the experimental dual-task, we presented the children with a straight-line drawing task in conjunction with an animal-naming task. On each trial, we presented an A4 landscape sheet with a 4 mm black dot centred vertically 28 mm from the left edge. A row of animal line drawings was printed at the top or on the bottom of the sheet (16 mm from the top or bottom edge). In the 'low-density' condition, five animals were spaced evenly between 31 mm from the left and right edges of the sheet, and in the 'high-density' condition, 10 animals were spaced evenly between 25 mm from the left and right edges of the sheet. The instruction was to start with the pen on the black dot, and to draw a straight line to the right hand edge of the sheet, naming any animals that the hand moved past. To assist with the naming task, the examiner pointed to each drawing that the hand moved past. Each child performed two blocks of four trials. In the first block, density was manipulated according to a repeating ABBA schedule, with the low-density condition first, and figure position alternated between trials, beginning with the animals at the top. This trial order was reversed in the second block and the order of the blocks was alternated between children.

4. Results

Fig. 2 shows selected examples of graphic performance in the preliminary line-copying task, and in the subsequent dual-task in which line drawing was combined with animal naming. The mean deviation of the drawn line away from the horizontal in each condition is shown in Fig. 3.

In the preliminary *line-copying single task*, the children's copies deviated slightly towards the top of the sheet, regardless of model position (leftmost part of Fig. 3). A paired *t*-test found no reliable difference between the mean deviations for the two model positions [$t(14) = .02$, $p = .98$]. A one-sample *t*-test on the grand mean deviation (collapsed across model position) confirmed that the upward deviation was reliably greater than zero [$t(14) = 2.49$, $p < .05$]. This overall tendency to veer towards the top of the sheet is of uncertain origin. However, it emphasises the importance of varying model position in the assessment of CIB, so that a true tendency to deviate towards the model can be disambiguated from broader default tendencies to deviate away from the centre of the page.

In the experimental *line drawing dual-task* (right side of Fig. 3), an overall tendency to deviate towards the top of the page was again apparent, slightly more so in the low-density condition, but overlaid on this was a strong tendency to deviate towards the animals being named, regardless of density condition. A repeated-measures ANOVA by animal

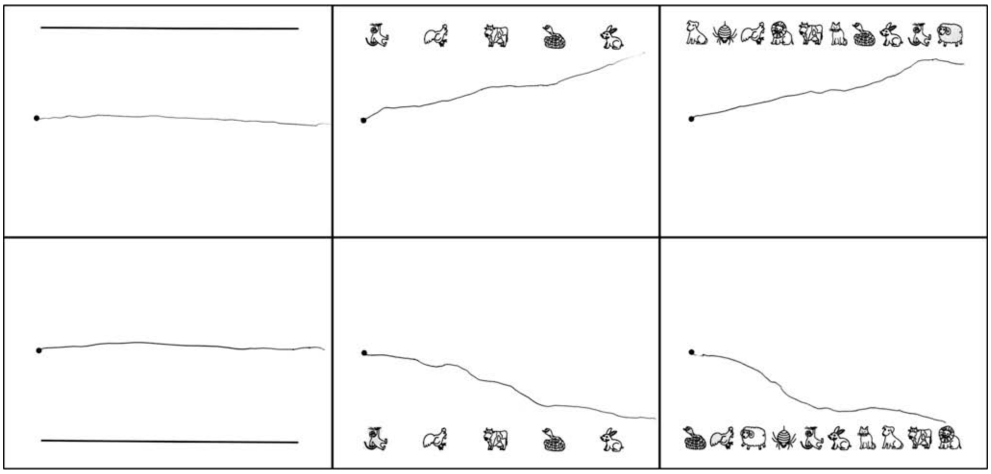

Fig. 2 – Selected examples of graphic performance in the preliminary line-copying task (left panels), and in the dual-task in which straight-line drawing was combined with animal naming: low-density (middle panels) and high-density (right panels) conditions. The dual-task illustrations show vivid examples of migration towards the animal-naming stimuli.

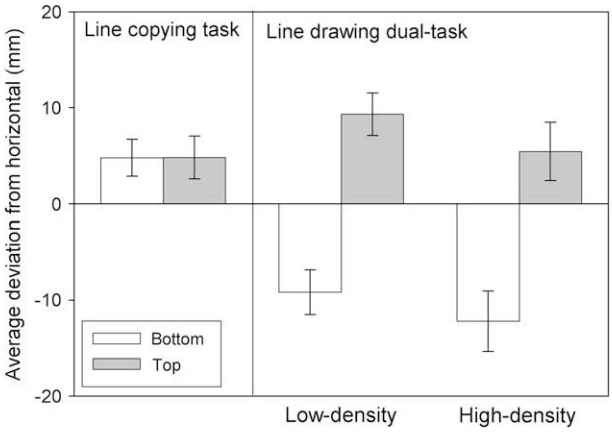

Fig. 3 – Mean deviation (± standard error) of the drawn line away from the horizontal in each condition, where positive is above and negative is below the level of the starting point (page midline). Unfilled and grey bars show performance with the model/naming stimuli at the bottom and top of the page, respectively.

position (bottom, top) and density (low, high) confirmed these impressions, finding reliable main effects of both factors [for position, $F(1,14) = 52.73$, $p < .0005$; for density, $F(1,14) = 4.74$; $p < .05$], but no reliable interaction [$F(1,14) = .24$, $p = .64$].

This deviation of drawn lines towards the location of visual attention defined by the naming task appears to mimic classical CIB, presumably depending upon similar underlying mechanisms. In order to investigate this point further, we evaluated the relationship between induced deviation towards the animals in the dual-task and spontaneous deviation towards the model during the preliminary copying tasks. For this analysis, deviation of the preliminary copy of the Luria figure was quantified in the same way as the deviation of the line in the dual-task. For the dual-task, mean deviation in each condition was recoded as positive if it was towards the animals named and as negative if it was away from the animals named; a grand mean deviation was then calculated across conditions. Pearson's correlation coefficient between tasks was .55 ($p < .05$), indicating that CIB in the dual-task could be predicted reliably from the Luria figure copying task. Deviation towards the animals in the dual-task could also be predicted from the mean CIB score rated across the nine geometrical figures of the preliminary copying tasks (Spearman's $\rho = .61$, $p < .05$).

5. Discussion

We examined the nature of graphic CIB in 15 children aged between four and six years. In line with previous literature (Gainotti, 1972; Mendilaharsu et al., 1970), our preliminary copying tasks confirmed the spontaneous occurrence of CIB in this age range, not tightly related to other aspects of copy quality, manifesting chiefly as the placement of copies close to or touching the model, with occasional instances of partial overlap. In several children, the laterally extensive Luria figure copying task elicited migration towards the model, as also observed in patients with Alzheimer's disease (Lee et al., 2004; McIntosh et al., 2008). Crucially, our experimental task, which combined simple straight-line drawing with concurrent visual naming, induced a similar migration. The extent of this migration in a given child was related reliably to prior copying of the Luria figure, and of more-standard geometric figures, suggesting that our dual-task did not merely mimic CIB in copying, but actually elicited the same phenomenon. The migration of drawing performance towards an *unrelated* visual stimulus cannot be explained by the compensation hypothesis, which assumes that CIB is a strategic adaptation to aid copying. On the other hand, this result is predicted precisely by the attraction hypothesis, according to which manual performance in susceptible groups should be drawn towards any sufficiently absorbing focus of visual attention.

The present experiment tested between competing hypotheses that have been proposed to explain CIB *in adults with dementia*. This is not to assume that the same factors underlie CIB in dementia and development, only that the same set of hypotheses is applicable, in principle, to children and adults alike. Nonetheless, the clear parallels between the manifestations and progression of the phenomenon in these different populations have encouraged several researchers to view them as functionally related, not just superficially similar (De Ajuriaguerra et al., 1960; Gainotti, 1972; Mendilaharsu et al., 1970). This possibility is bolstered by the fact that the present findings closely replicate some results obtained recently from a 62-year old woman (WS) with moderate Alzheimer's disease and pronounced CIB (McIntosh et al., 2008). Patient WS performed a straight-line drawing task concurrently with a letter-reading task, and veered markedly towards the letter stimuli, as predicted by the attraction hypothesis.

The alternation of visual naming stimuli between the top and bottom of the page in our design allowed us to distinguish true migration towards those stimuli from other directional biases in drawing. Indeed, the straight-line-copying task performed prior to the main experiment revealed that the children tended to drift slightly (~5 mm) but significantly upward from their starting point, regardless of model position. A similar drift exists in healthy adults (Lee et al., 2004), reminiscent perhaps of the distal attentional bias observed in normal subjects performing radial line bisection (Halligan and Marshall, 1993; Shelton et al., 1990). If pronounced, such drift could masquerade as CIB whenever the model was at the top of the page. We therefore suggest that at least two model positions should be used for the future assessment of this behaviour.

In addition to manipulating model position, we also manipulated the density of the visual naming stimuli, with the expectation that the greater requirement for focused attention to naming stimuli in the high-density condition would amplify any manual migration effects. Instead, a simple main effect of stimulus density emerged, such that upward drift was reduced overall in the high-density condition. We have no principled account to offer for this finding, but note that this main effect does not pertain at all to CIB, which was tested specifically by the effect of model position upon drawing position. The fact that the effect of model position (CIB) did not interact with stimulus density suggests that the difference between low- and high-density stimuli may have been too subtle to substantially alter the degree of visual monitoring of the animal-naming stimuli (or that a ceiling level of monitoring was induced in the low-density condition). Alternatively, the examiner's finger, tracking progress along the row of stimuli, may have provided a constant visual focus that acted to minimise differences between low and high-density conditions. A lack of modulation of CIB between low- and high-density visual naming conditions was also observed in our patient WS (McIntosh et al., 2008), perhaps for similar reasons.

The similarity of the graphic performances of the children and patient WS supports the view that common factors underlie CIB in development and dementia. Having thus rejected the compensation hypothesis in children and in a patient with dementia, the next step is to specify the attraction hypothesis more fully. The hypothesis posits a default manual attraction towards the focus of visual attention. This idea resonates with research suggesting that attention-attracting visual stimuli recruit motor programs automatically, which must be actively suppressed in order to prevent responses towards these stimuli from contaminating ongoing behaviour (e.g., Tipper et al., 1998). However, the bare hypothesis does not state which cognitive factors promote the release of this default tendency. Kwon et al. (2002) have suggested that the crucial precipitant is a deficiency of executive and/or attentional resources. Copying tasks may inherently possess the quality of a dual-task, requiring the efficient division or switching of attention between model and copy. A deficit in executive control, which would be needed to inhibit analysis of the model in order to switch attention to monitoring copy production, could plausibly underlie the release of the default tendency to migrate towards the model.

In support of this view, it should be noted that CIB can indeed accompany deficits in the inhibition of automatic responses (Conson et al., 2009, this issue), and that it may be pronounced following a frontal lobe lesion (Lepore et al., 2005). The symptom has also been observed in frontal syndromes associated with epilepsy, both in children (Hernandez et al., 2002) and adults (Septien et al., 1992). Moreover, CIB in clock-copying (defined as a model-directed mislocation of numbers), amongst patients with mild dementia, has been found to be associated with white matter lesions and poor performance on executive tasks (Cosentino et al., 2004). The hypothesis that attentional and/or executive deficits underlie CIB thus finds some support in the neuropsychological literature, and offers a tractable starting point for future investigations.

Of course, even if attentional deficits are necessary for the emergence of CIB, it is likely that the behaviour could be exacerbated by other cognitive deficiencies that might co-exist with these problems. In general, we might suppose that any factors that increase the difficulty of the copying task will tend to amplify CIB by placing additional load upon the cognitive system. Such factors might be external to the system: for instance, increased figure complexity, which has several times been reported to exacerbate CIB (e.g., Lee et al., 2004; Mayer-Gross, 1935; McIntosh et al., 2008; Muncie, 1938). Alternatively, they might be internal factors, such as deficiencies of visuospatial abilities or working memory. These considerations suggest that the search for cognitive correlates of CIB could be expected to throw up multiple candidates. In accord with Kwon et al. (2002), however, we hypothesise that the most powerful unique predictor of CIB should relate specifically to attentional functions. We are now testing this prediction, both in children and in adults with Alzheimer's disease. We are also assessing whether the addition of attention-demanding secondary-tasks to figure copying can induce model-directed migration in normal subjects.

Finally, it is prudent to issue a caveat regarding the simulation of CIB that has been achieved in the present study. Although our dual-task was successful in eliciting migration towards the visual focus, the effects were limited to this pattern of veering. Notably, we did not induce any extreme examples of drawing or scribbling over the naming stimuli. This could reflect a restriction inherent to our sample, since the most extreme manifestations of CIB in the preliminary copying tasks were a few instances of partial overlap, and no overlap at all was observed for the Luria figure. Provided that migratory CIB (encroachment on the model) lies on a continuum of severity with the contact and overlap forms, then it might seem safe to assume that our conclusions can generalise to the phenomenon as whole. However, the assumption that the different forms of CIB lie on a continuum, and share common causes, is still untested. Accordingly, our present conclusion in favour of the attraction hypothesis should be taken to apply strictly to the more subtle, migratory form of CIB, and only tentatively to extend to more dramatic manifestations.

The cognitive factors underlying the release of the default tendency, to respond towards the spatial focus of attention, are uncertain, but we have speculated that attentional deficiencies may be critical (see also Kwon et al., 2002). Whether or not this speculation holds up to further scrutiny, the present study at least shows that CIB is not specific to copying tasks, but is a more general phenomenon. The view that this behaviour betrays a specifically constructional deficit should therefore be re-evaluated.

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