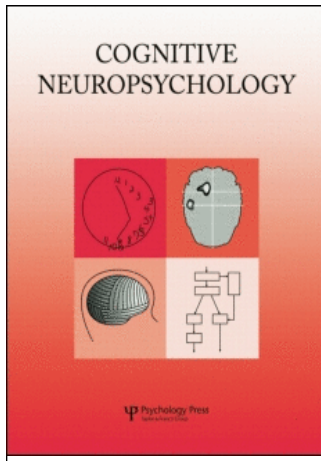


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On: 2 July 2008  
Access Details: [subscription number 789189099]  
Publisher: Psychology Press  
Informa Ltd Registered in England and Wales Registered Number: 1072954  
Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK



## Cognitive Neuropsychology

Publication details, including instructions for authors and subscription information:  
<http://www.informaworld.com/smpp/title~content=t713659042>

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Online Publication Date: 01 May 2008

To cite this Article: Mcintosh, Robert D., Ambron, Elisabetta and Della Sala, Sergio (2008) 'Evidence for an attraction account of closing-in behaviour', Cognitive Neuropsychology, 25:3, 376 — 394

To link to this article: DOI: 10.1080/02643290802028981

URL: <http://dx.doi.org/10.1080/02643290802028981>

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# Evidence for an attraction account of closing-in behaviour

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“Closing-in behaviour” (CIB) is a phenomenon observed on copying and imitation tasks, in which the copy is made inappropriately close to or on top of the model. CIB is classified clinically as a manifestation of constructional apraxia (CA), but its underlying causes are not understood. Compensation hypotheses propose that CIB is a strategic adaptation to underlying deficits in visuospatial and/or memory functions. The attraction hypothesis suggests that CIB reflects a primitive default behaviour in which the acting hand is drawn towards the focus of visual attention. We tested between these hypotheses in a 62-year-old woman with moderate Alzheimer’s disease precipitating CA and apraxia, who showed marked CIB in graphic copying and gesture imitation. We presented two dual tasks: In the first, a straight-line drawing task was combined with a letter-reading task; in the second, simple gesture production was combined with a letter-reading task. In each case, the patient’s productions deviated markedly towards the location of the reading task. These data provide strong support for the attraction hypothesis and show that CIB is not specific to copying.

**Keywords:** Alzheimer’s disease; Apraxia; Closing-in behaviour; Constructional apraxia; Copying; Drawing.

Constructional apraxia (CA) is a broad clinical label for impaired drawing or building performance (Kleist, 1934). Constructional tasks demand

diverse cognitive abilities, and such a variety of errors can arise that this broad label cannot be taken to imply any specific cognitive impairment

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The authors are grateful to W.S. and her husband for their friendship and cooperation, to Philip Bryers and the Scottish Dementia Working Group for assistance with recruitment and testing, and to Thomas H. Bak for advice on the interpretation of the Addenbrooke’s Cognitive Examination (ACE) subscores. This work was supported by the Moray Endowment Fund of the University of Edinburgh.

(Farah, 2003). Moreover, where constructional errors are recognized as characteristic of specific cognitive impairments, they tend to attract the specific labels (e.g., perseveration, neglect), rather than being classified as CA. It can thus be argued that CA operates, clinically, as an umbrella term for heterogeneous drawing or building errors of unknown cognitive origin.

One idiosyncratic manifestation of CA that has received relatively little attention in the neuropsychological literature was first described by Mayer Gross (1935) in a patient with carbon monoxide poisoning and in five patients with progressive mental deterioration (i.e., probable dementia). These patients were able to copy simple geometric figures, whether by drawing or arranging mosaic tiles or blocks, but when the complexity of the model increased they would attempt to copy directly next to, or even on top of the model. A similar tendency emerged in the imitation of hand postures, during which the patient's hand would sometimes overlap that of the examiner. Mayer Gross viewed these behaviours, within a broader theory of CA, as manifestations of a "primary biological protection mechanism" related to the "fear of empty space" (p. 71). His theoretical interpretation, however, has had a less enduring influence than his coinage of the term "closing-in" behaviour (CIB) to describe the peculiar attraction to the model.

Scattered case reports featuring similar phenomena appeared in the literature subsequently, confirming that an attraction towards a model can arise across a wide range of copying tasks (e.g., graphic, 3D construction, gesture, writing) and diverse neuropathologies (dementia, cerebral stroke, carbon monoxide poisoning, corticobasal degeneration, encephalitis, epilepsy; Critchley, 1953; De Ajuriaguerra, Zazzo, & Granjon, 1949; Denny-Brown, 1958; De Renzi, 1959; Grossi, Calise, Correr, & Trojano, 1996; Kwon et al., 2002; Lepore, Conson, Grossi, & Trojano, 2005; Lhermitte & Mouzon, 1941; Muncie, 1938; Septien, Giroud, Sautreaux, & Dumas, 1992; Stengel & Vienna, 1944; Vereecken, 1958). These observations, often incidental to the thrust of the report, were not always

recognized by their authors as being related to Mayer Gross's category of CIB. Nonetheless, it seems reasonable to suppose that the conceptual linkage between them reflects a degree of dependence on common mechanisms, suggesting that CIB is a rather general phenomenon, not associated with any narrow range of constructional demands. Indeed, it may not even be specific to copying tasks, as some authors have noted the tendency for a patient's performance to "close-in" towards earlier parts of their own productions during drawing (Suzuki et al., 2003) or writing (De Ajuriaguerra et al., 1949).

A few group studies have investigated the incidence and severity of CIB (for graphic copying) in different pathological conditions. Direct comparisons between studies are complicated by differences in tasks and qualitative criteria for the classification of CIB, but several broad patterns can be discerned. First, the incidence of this symptom is low in unselected patients with focal cerebral infarcts (7.5%) or mild dementia (6%), but rises dramatically with progression of dementia through moderate (42%) and severe (61%) stages (estimates from Gainotti, 1972; see also De Ajuriaguerra, Muller, & Tissot, 1960). Second, the average severity of CIB tracks a parallel course, accompanied by deterioration in the quality of the reproduction, progressing from encroachment of the copy on the model, to overlap between the copy and the model, with unrecognizable scrawling over the model as the end-state (Gainotti, 1972). Third, CIB is common in Alzheimer's disease (AD; Ober, Jagust, Koss, Delis, & Friedland, 1991; Rouleau, Salmon, & Butters, 1996; Spinnler & Della Sala, 1988, p. 263), and more prevalent than in several other forms of dementia, including vascular dementia (Gainotti, Parlato, Monteleone, & Carlomagno, 1992) subcortical vascular dementia (Kwack, Han, & Kim, 2002), and multi-infarct dementia (Gainotti, Marra, Villa, Parlato, & Chiarotti, 1998; Grossi, Orsini, & De Michele, 1978; Midorikawa, Fukatsu, & Takahata, 1996). Although the sensitivity of CIB to AD may not be especially high, at least in mild stages of the disease, its specificity for AD has been estimated

at around 80% compared with vascular and subcortical vascular dementia (Gainotti et al., 1998; Kwack, 2004). A principled understanding of the mechanisms underlying CIB might thus be informative regarding the specific cognitive character of AD.

Our focus in this paper is on CIB as a neuropathological symptom, but it should be noted that similar phenomena can be observed in early childhood. Prudhommeau (1947) identified this tendency in the development of graphic abilities, and Wallon and Lurçat (1957) similarly emphasized an “attraction to what already exists” in young children and in children with “mental deficiencies”. Although some authors had drawn parallels between the development of graphic abilities in childhood and their deterioration in dementia (De Ajuriaguerra et al., 1960; Muncie, 1938), Mendilaharsu, Delfino de Cultelli, and Saprizza de Correa (1970) were the first to study children’s copying specifically with regard to Mayer Gross’s category of CIB. The analogy was made even more explicit by Gainotti (1972), who assessed 118 children aged from 2 to 6 years and 132 patients with dementia on the same graphic copying battery and with the same criteria for the evaluation of CIB. The average developmental pattern of CIB mirror-reversed the trajectory in dementia: The children progressed from scrawling on the model, to overlap, to encroachment, and finally to a full separation of copy from model by 6 years of age. These superficial similarities do not necessarily imply that common factors underlie CIB in development and dementia, but such a possibility would be consistent with the notion that primitive behavioural patterns may reappear in neuropathology due to the disruption of higher executive mechanisms (De Ajuriaguerra et al., 1960; Gregory, 2001).

To date, the cognitive basis of CIB has been little investigated. However, it is possible to distinguish two main contemporary candidate hypotheses. The “compensation” hypothesis, probably traceable to Muncie (1938), proposes that CIB reflects a strategic adaptation to an underlying cognitive impairment. On this view, CIB emerges as an attempt to compensate for an

impaired ability to represent the model (Lee et al., 2004) and/or to retain that representation across the intervals required to make a spatially removed copy (Kwon et al., 2002; Lee et al., 2004). By decreasing the distance between copy and model, the burden on visuospatial analysis and/or working memory can be reduced. In the limit, this strategy would convert the copying task into a direct tracing task, relieving the patient of the need to set up or store an abstract representation of the model at all.

An alternative hypothesis is that CIB represents 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). In its bare form, the “attraction” hypothesis is underspecified, since it is not clear what precipitates the release of this default behaviour. Kwon et al. (2002) have suggested that the precipitating condition is frontal dysfunction, implying a deficiency of executive and/or attentional resources (see also Gainotti, 1972; Lepore et al., 2005). 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 attraction hypothesis, CIB is not strategic and would not be expected to aid copying performance; it is merely a default state released by a breakdown of normal control processes.

There have been two recent attempts to test the above hypotheses. Kwon et al. (2002) studied a patient with corticobasal degeneration, who exhibited CIB in gesture imitation. The experiment was designed to test the compensation hypothesis, with the prediction that CIB should be more pronounced when gesture complexity was increased, or when a more complex spatial transformation was demanded by having the patient sit facing, rather than alongside, the examiner. However, no reliable influence of either manipulation was observed, which led the authors to reject the compensation hypothesis in favour of an attraction account. Subsequently, Lee et al. (2004) tested a group of 13 patients with AD on a graphic copying task, presenting horizontally extensive “Luria” figures and estimating the slope of the

patients' copies as an index of CIB. In this experiment, both figure complexity and the distance of the designated starting position from the model were manipulated. The prediction drawn from the compensation hypothesis was that complexity should increase CIB by adding to the visuospatial and memory load, and that compensation would be more pronounced for starting positions further from the model. The data robustly confirmed the expected effect of complexity, but no reliable influence of starting position was obtained. Nonetheless, the authors concluded in favour of the view that CIB arises as a strategic compensation for visuospatial or working-memory dysfunction.

How can we reconcile the apparently conflicting findings of these two studies? On the one hand, Kwon et al.'s (2002) conclusion in favour of an attraction account was based upon their failure to find a significant influence of task complexity, but this is contrary to the weight of evidence, which indicates that figure complexity is a cardinal determinant of CIB (e.g., Lee et al., 2004; Mayer Gross, 1935; Muncie, 1938). It would thus seem unwise to base any firm or general conclusions on this isolated null finding, especially given that a single case of possibly atypical CIB (associated with corticobasal degeneration) was studied. On the other hand, Lee et al.'s (2004) support for the compensation hypothesis was based entirely upon the effect of figure complexity. However, it can be argued that this does not constitute a critical test between compensation and attraction accounts. The attraction account proposes that the acting hand is drawn to the focus of visual attention, so any manipulation that increases focal attention to the model might be expected to exaggerate this effect. We would thus argue that the observed effects of figure complexity are fully compatible with an attraction account or the compensation hypothesis, and do not provide unequivocal support for either. A more decisive empirical test is required.

The most obvious factor distinguishing the compensation and attraction hypotheses is that in the former, CIB is a functionally adaptive

strategy to aid copying performance, whilst in the latter it is nonfunctional, arising only because the patient fails to inhibit a default behaviour. The compensation hypothesis thus 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 patients with CIB should migrate towards any sufficiently attention-demanding visual stimulus, regardless of its relevance to the manual task. In this paper, we test these predictions in a patient with AD and CIB. We report a clear effect of figure complexity on CIB in both graphic and gestural copying tasks. Critically, we also show that manual performance is strongly attracted towards the focus of attention defined by an unrelated visual discrimination. These data demonstrate that CIB is not specific to copying tasks and provide firm evidence for the attraction hypothesis over compensation accounts, at least for this patient. In discussing these findings, we further consider what cognitive factors might underlie the release of a primitive manual attraction towards the focus of visual attention.

## Materials and method

### *Case report*

Patient W.S. was a 62-year-old woman who had been diagnosed with AD three years prior to this study. W.S. was aware of her diagnosis and of her cognitive difficulties, showing frustration, and sometimes distress, when unable to complete tests to her satisfaction. However, she was cooperative and motivated throughout our assessments, which were conducted over a 10-month period.

### *General cognitive status*

At the first assessment, W.S.'s dementia was classified as "moderate", according to the Washington University Clinical Dementia Rating (Morris, 1993). She scored 63/100 in the Addenbrooke's Cognitive Examination (ACE: Mathuranath, Nestor, Berrios, Rakowicz, & Hodges, 2000) and achieved 21/30 in the Mini-Mental State Examination (MMSE). W.S.

showed constructional apraxia and CIB in the graphic copying parts of the ACE, producing no recognizable reproductions, but scrawling near to or on top of the models. At the final assessment, the ACE was readministered: W.S.'s total score (54) and MMSE subscore (17) were reduced relative to the first assessment, suggesting moderate progression of dementia over the course of the present studies.

The profile of subscores on the ACE, averaged across the two assessments, suggested typical memory problems (19/35), mild impairments of orientation (5.5/10) and attention (5/8), and poor verbal fluency (4.5/14) in the context of relatively preserved language (24/28). A pronounced impairment of visuospatial abilities (0.5/5) was observed on constructional and writing tasks; constructional abilities were explored more extensively using further copying tasks (see *Assessment of CA*, below).

#### *Further neuropsychological assessments*

W.S.'s husband reported a slight tendency for her to neglect the left side, which was confirmed by the administration of Albert's (1973) line cancellation test. W.S. cancelled only 23 of the 36 lines on this test, with more than twice as many omissions on the left side of the sheet as on the right (10 vs. 3); she also tended to perseverate, cancelling eight of the lines more than once. W.S. showed no sign of optic ataxia, being able to reach accurately, with either hand, to targets in both visual hemifields.

We additionally attempted to assess cognitive functions of primary relevance to the compensation and attraction hypotheses of CIB. Assessment included the Digit Span Test of the Wechsler Adult Intelligence Scale-Revised (WAIS-R; Wechsler, 1981), for verbal memory, and the Corsi blocks task (Corsi, 1972) and Visual Patterns Test (VPT; Della Sala, Gray, Baddeley, & Wilson, 1997) for spatial and visual working memory, respectively. W.S.'s digit spans were 6 (forward) and 3 (backward), giving an overall age-scaled score of 6 (within 2 *SDs* of the normal mean). Her Corsi block span of 2 was well below the normal range ( $z = -2.92$ ).

Unfortunately, she had difficulty following the instructions for the VPT, becoming confused and distressed, and this test was abandoned. Similar problems bedevilled our attempts to assess attentional functions using the, relatively complex, map search, visual elevator, and elevator counting subtests of the Test of Everyday Attention (Robertson, Ward, Ridgeway, & Nimmo-Smith, 1994); no meaningful scores could be derived from these.

These assessments lend circumstantial support to the idea that CIB is associated with impaired visuospatial functions and/or working memory. W.S.'s low Corsi span is indicative of poor visuospatial working memory, which may be related to the poor visuospatial abilities indicated by her ACE profile. However, caution should be exercised here, since the neuropsychological tests employed are relatively nonspecific (e.g., the Corsi blocks task has significant executive components: Richardson, 2007; Rudkin, Pearson, & Logie, 2007) and since W.S.'s inability to perform several tests implies pervasive cognitive difficulties. The association of visuospatial impairments and CIB in this patient does not establish any causal connection, although it may inform the interpretation of our experimental results.

#### *Assessment of CA*

To provide a fuller assessment of graphic copying performance, we asked W.S. to copy nine pictures, three at each of three levels of complexity: simple, medium, and complex. The simple stimuli were geometrical figures (square, circle, and triangle); the medium-complexity stimuli were overlapped pairs of geometrical figures (overlapped squares, ellipses, and triangles); the complex stimuli were two-dimensional representations of three-dimensional figures (cube, cylinder, and pyramid). Each stimulus was presented within the left half of an A4 sheet, in landscape orientation. W.S. did not produce a single recognizable reproduction in these trials. Moreover, CIB was observed consistently, with six from nine of the attempted reproductions touching or overlapping the model in some part (see Figure 1 for examples).

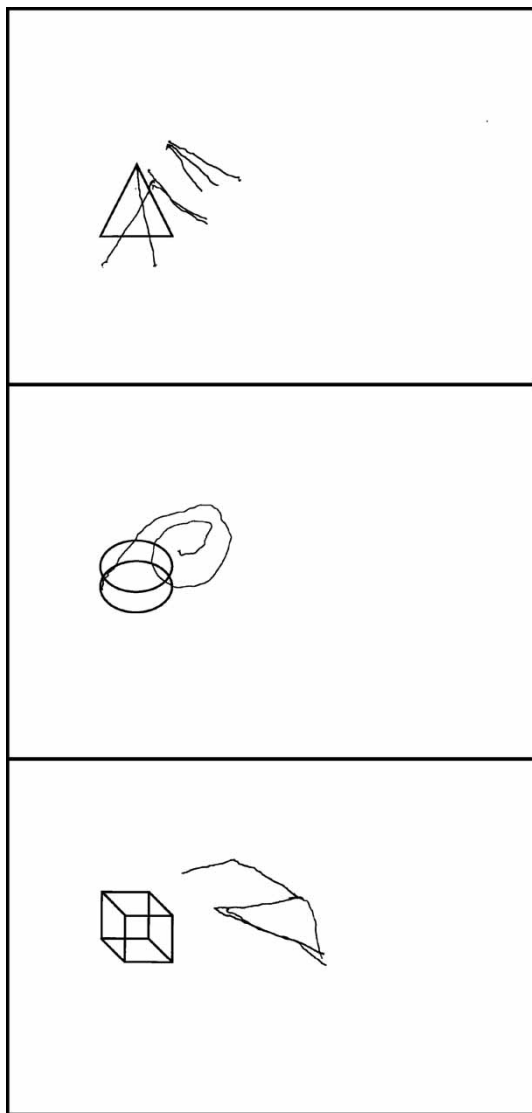


Figure 1. Representative examples of W.S.'s attempted reproductions in the graphic copying screening task, showing pronounced constructional apraxia (CA) and closing-in behaviour (CIB).

#### Assessment of apraxia

W.S.'s performance in copying gestures was assessed using a range of unimanual gestures. Six transitive gestures (e.g., writing with a pen, cutting with scissors) and six intransitive gestures (e.g., peace sign, beckoning with finger) were

selected from Bartolo, Cubelli, and Della Sala, (2008), and seven meaningless gestures (e.g., palm down, fist up) were selected from Kwon et al. (2002). Each gesture was first attempted in response to a verbal instruction and then in imitation of the examiner, with gesture type blocked (as recommended by Cubelli, Bartolo, Nichelli, & Della Sala, 2006). The transitive gestures were then reperformed as a pantomime (i.e., without the object present): first to verbal instruction, next in imitation of the examiner without the object being named, and finally in imitation of the examiner with the object name spoken. Throughout this assessment, the examiner faced W.S. across a small table, with a 64 × 46-cm sheet of paper placed between them, oriented horizontally. This sheet was divided in half lengthways by a thick black line. At the outset, and at regular intervals, it was emphasized to W.S. that she should perform her movements in her own workspace, on her side of the black line. Both the examiner and W.S. performed all gestures with the right hand.

For each gesture, the accuracy of reproduction was rated on a scale of 0–2, according to the following descriptors:

- 0: The gesture is different from the one required.
- 1: The gesture is similar to the one required.
- 2: The gesture is correct.

CIB was also rated on a scale of 0–2, using the tendency to respond towards the examiner's side of the workspace as the criterion:

- 0: The gesture is performed in the examiner's workspace.
- 1: The gesture is performed on top of the dividing line between workspaces.
- 2: The gesture is performed in the patient's own workspace.

The apraxia assessment data were not sufficiently extensive to support statistical analysis, but some qualitative trends can be sketched. First, in terms of gesture quality, W.S. performed relatively well for transitive gestures using real objects (mean score 1.84), but less well when imitating a pantomime with the object named (mean

score 1.50), and more poorly again when imitating a pantomime without the name (mean score 1.17) or pantomiming to verbal instruction (mean score 1.17). Relative to transitive gestures using real objects, intransitive and meaningless gestures were performed poorly overall (mean scores 1.34 and 1.43, respectively).

Within a contemporary cognitive model of apraxia, this pattern could suggest a generalized impairment of the praxic system, selectively sparing object use at the level of the praxis output lexicon (Cubelli, Marchetti, Boscolo, & Della Sala, 2000). This relative sparing could be an epiphenomenon induced by the patient's general reduction of available cognitive resources: Affordance-like effects produced by the additional tactile and kinaesthetic information could make the use of a real object easier than analysing complex meaningless configurations, or accessing the working-memory system to process pantomimes (Bartolo, Cubelli, Della Sala, & Drei, 2003).

In terms of CIB, the patterns of performance were clear and unsurprising. CIB emerged only mildly when gestures were instructed verbally (mean score 1.50), but much more strongly across the various imitation conditions (mean score 0.66), in which there was a model to copy from and to migrate towards.

## EXPERIMENT 1: CIB IN GRAPHIC TASKS

### Procedure

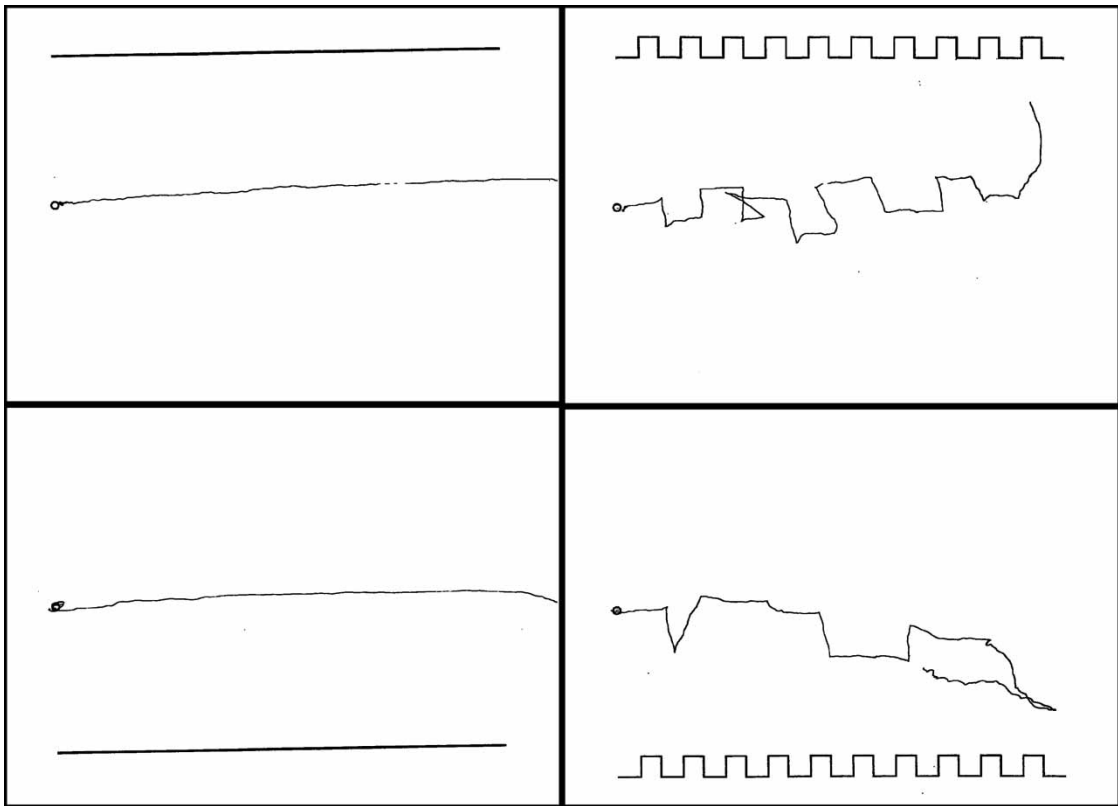
#### *Preliminary graphic copying task*

Patient W.S. was asked to copy two simple figures, presented on A3 paper in landscape orientation on a tabletop. The simpler figure was a straight black line; the more complex figure was a "Luria figure" (after Luria, 1966) with 10 square units; each model was 340 mm long, centred on the long axis of the paper, and was presented 41 mm from

the top or bottom edge of the paper (see Figure 2). Each sheet also had a black dot (6 mm diameter) centred vertically on the sheet, in horizontal alignment with the left end of the model.<sup>1</sup> The instruction was to place the pen on the starting point at the centre of the dot and to copy the model from left to right. Two blocks of 12 trials were attempted, one before the experimental task (see below) and the other after it. In the first block, figure complexity was manipulated according to a repeating ABBA schedule, with the simple figure first, and figure position alternated between trials, beginning with the figure at the top. This trial order was reversed in the second block. Unfortunately, the first block of trials was curtailed, resulting in a reduced number of trials for this block (see Results section).

CIB on the drawing task was quantified by two alternative dependent variables. First, the average deviation of the drawn line from the centre of the page was estimated by averaging the vertical coordinates of the line at the horizontal coordinate of the start position and at successive rightward increments of 20 mm until the right-hand edge of the paper was reached or the drawn line was no longer present. Deviations towards the model were signed positively, and deviations away from the model were signed negatively, and this value was expressed as a percentage of the vertical distance between start position and model. Additionally, following the method of Lee et al. (2004), we regressed the vertical coordinates upon the horizontal coordinates for each trial, taking the slope of the best fitting straight line as the dependent variable. Assuming that a linear relationship is obtained, the slope indexes the degree to which the drawn line veers away from the horizontal on a given trial, with veering towards the model producing a positive slope, and veering away from the model a negative slope. Extensive piloting of versions of this task indicated that normal adults show no tendency to deviate towards the model, although they may

<sup>1</sup> The terms "horizontal" and "vertical" are henceforth used to refer to the long and short axes of the landscape page, respectively. However, it should be noted that, since the page was presented on a tabletop, the "vertical" axis was actually oriented in depth, parallel to W.S.'s sagittal axis.



**Figure 2.** Representative examples of W.S.'s performance in the preliminary graphic copying task of Experiment 1, showing closing-in behaviour (CIB) for the more complex Luria figure. The examples selected are the individual trials in which the CIB score (deviation towards the model) was closest to the mean score in the corresponding condition.

have a default tendency to drift upwards slightly (see Lee et al., 2004).

*Preliminary letter-reading task*

We also checked W.S.'s ability to read random letters of the alphabet, printed at 32 point in upper or lower case and in various fonts (Times New Roman, Monotype Corsiva, Arial, and Tahoma). W.S. was able to name these letters without hesitation, suggesting that this would constitute a suitable visual discrimination task for the experimental dual task to follow.

*Experimental dual task*

In the experimental task, W.S. was required to perform a straight-line drawing task and a letter-reading task simultaneously, using a similar

set-up and scoring system as those in the preliminary graphic copying task. On each trial, we presented a sheet of A3 paper in landscape orientation with a 6-mm diameter black dot, as before, centred vertically 63 mm from the left edge. Along the top or bottom of the sheet (35 mm from the top or bottom edge) was a row of random letters printed at 32 point in upper or lower case and in various fonts. There were either 10 or 20 letters, spaced evenly and spanning from 63 mm from the left edge of the sheet to 63 mm from the right edge. In the 10-letters condition, the interletter spacing was 22 mm; in the 20-letters condition, the interletter spacing was 10 mm. On each trial, W.S. was instructed to draw a straight line from the starting point to the right-hand edge of the paper whilst naming any

letters that her hand moved past. To assist with the reading requirement, the examiner pointed to each letter that the hand moved past. Two blocks of 12 trials were performed. In the first block, letter density was manipulated according to a repeating ABBA schedule, with the 10-letter condition first, and figure position alternated between trials, beginning with the figure at the top. This trial order was reversed in the second block.

## Results

### *Preliminary graphic copying task*

Figure 2 shows representative examples of W.S.'s performance in the preliminary graphic copying task. For the Luria figure she produced very poor reproductions that tended to close in markedly towards the model. Unfortunately, during the first block of trials, W.S. became acutely distressed by her inability to copy the Luria figure and requested to stop the task after only seven trials. Moreover, two of the attempted copies of the Luria figure consisted of fragmented lines in various positions on the sheet (mostly near the model), from which no satisfactory measure of CIB could be derived, and these trials were considered void. This resulted in a total of seven lost trials from the first block. W.S. was more composed during the second block, completing all trials. In both blocks, W.S. experienced obvious difficulties with the Luria figure only; she was always able to copy the simple horizontal line, with no visible tendency toward CIB.

Statistical analyses of mean deviations confirmed these impressions. One-way  $t$  tests versus zero found that the mean deviation towards the model was not reliable for the simple model (mean = 1%,  $SD = 13$ );  $t(9) = 0.25$ , *ns*, but was reliable for the complex model (mean = 15%,  $SD = 12$ );  $t(6) = 3.26$ ;  $p < .05$ . An independent  $t$  test found that the difference between simple and complex conditions was reliable,  $t(15) = 2.31$ ;  $p < .05$ . The ability to produce the straight line is important, as it establishes that W.S. understood the task instructions adequately, ruling out any explanation of CIB based on a simple misunderstanding of task instructions.

Analysis of the slope measurement produced different statistical outcomes. One-way  $t$  tests versus zero found no reliable mean deviation towards the model for either the simple model (mean = 0.02,  $SD = 0.05$ );  $t(9) = 1.02$ , *ns*, or the complex model (mean = 0.11,  $SD = 0.13$ );  $t(6) = 2.22$ ; *ns*. An independent  $t$  test found no reliable difference in slope between the simple and complex conditions,  $t(7.07) = 1.83$ ; *ns*. However, we consider the former measure, of mean deviation, to be more representative of performance than the slope measure, the practical shortcomings of which will be considered in the Comment section below.

### *Experimental dual task*

Figure 3 shows representative examples of W.S.'s performance in each experimental condition for the dual task. W.S.'s drawn line veered towards the letters read on every trial, and this was not obviously affected by the density of the letters.

Statistical analysis was performed on the mean deviations and slopes of W.S.'s drawn lines. One-way  $t$  tests versus zero found that the mean deviation towards the letters was reliable for both the 10-letter (mean = 33%;  $SD = 18$ );  $t(11) = 6.22$ ;  $p < .001$ , and 20-letter conditions (mean = 31%;  $SD = 14$ );  $t(11) = 7.49$ ;  $p < .001$ . An independent  $t$  test found no reliable difference between these conditions,  $t(22) = 0.17$ ; *ns*.

Similar results were found in the analysis of slope. The mean slope of the line drawings was reliably greater than zero for both the 10-letter (mean = 0.21;  $SD = 0.11$ );  $t(11) = 6.41$ ;  $p < .001$ , and 20-letter conditions (mean = 0.21;  $SD = 0.06$ );  $t(11) = 10.69$ ;  $p < .001$ . An independent  $t$  test found no reliable difference between these conditions,  $t(22) = 0.22$ ; *ns*.

## Comment

Some relevant methodological issues relating to the assessment and quantification of CIB are raised by the outcome of Experiment 1. Like Lee et al. (2004), we used "Luria" figures, composed of sequential subelements, for the assessment of graphic CIB. These are readily amenable to

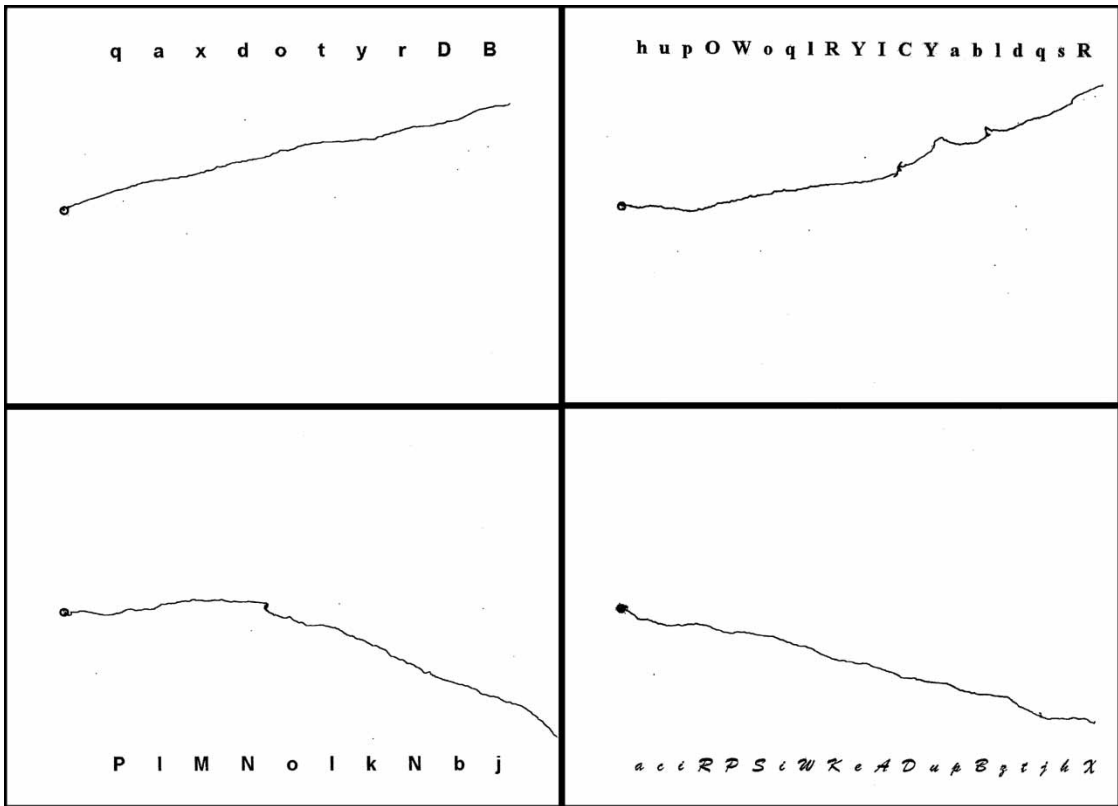


Figure 3. Representative examples of W.S.'s performance in the dual task of Experiment 1, showing pronounced veering towards the letter stimuli in all conditions. The examples selected are the individual trials in which the closing-in behaviour (CIB) score (deviation towards the model) was closest to the mean score in the corresponding condition.

manipulations of task complexity, via modulation of the variety and/or predictability of subelements. Additionally, since the figures are laterally extensive, they allow CIB to develop over time, and its evolution is recorded along the left-right axis. Lee et al. measured the vertical coordinate of the copy at 2-mm intervals along the horizontal axis, with the slope of the regression line between these providing their index of CIB. In our Experiment 1, this measure proved less sensitive to CIB than was a simple estimate of the mean vertical coordinate.

One problematic aspect of the slope measure, which may account for its reduced sensitivity, is that it assumes a linear migration of the copy and one that does not reach a ceiling level of proximity to the model, an assumption that does not

always hold. Whilst patient W.S. often did show strongly linear manual migration (median  $r^2$  in Experiment 1 dual task = .94), this relationship was sometimes depressed ( $r^2 < .90$  in 33% of trials) by an initial period of stability or a terminal ceiling level of proximity. In one trial, there was a clear indication of severe CIB followed by corrective migration away from the model, which seriously disrupted the slope measure ( $r^2 = .42$ ). We therefore believe that the average vertical coordinate provides a more robust measure of CIB, applicable across a wider range of behaviour.

It is notable that Lee et al. (2004) excluded from their study AD patients in whom early ceiling levels of CIB were observed on the Luria task. We have similarly encountered patients in whom the migration towards the model is almost immediate

(see Figure 4). Whether such extreme, “instant” CIB reflects a difference of degree or quality from the more gradual migration reported in the present study is a matter for future investigation.

A further methodological consideration is the use, in our design, of models placed both at the top and at the bottom of the copying sheet. In testing for CIB, it is essential to vary the model position in order to confirm that any migratory effects are specifically model-directed. For instance, the healthy control sample reported in Lee et al. (2004) showed a subtle but reliable tendency to move up the page, which was interpreted as migration towards the model. Unfortunately,

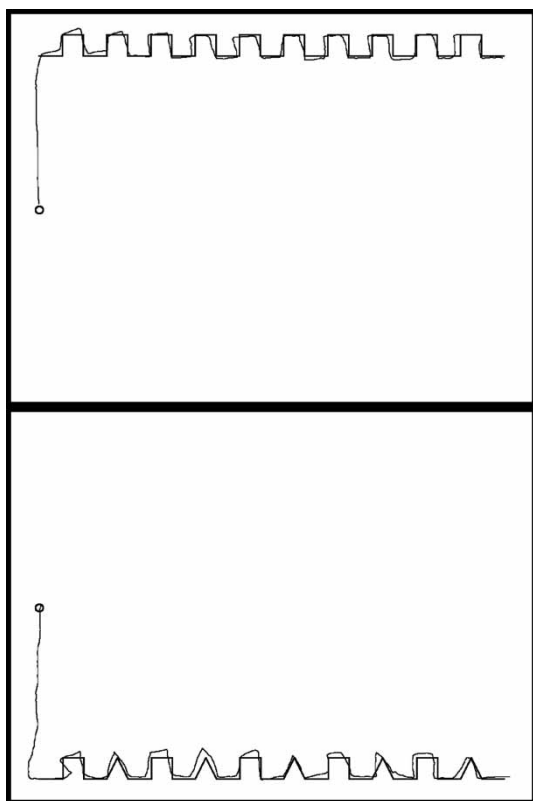
since the model was always positioned at the top of the page, this interpretation cannot be distinguished from the possibility that the healthy participants had a default tendency to drift upward regardless of model position. In principle, a similar uncertainty pertains to the behaviour of Lee et al.’s AD group, though the present results strongly endorse their interpretation of the observed migrations as CIB.

## EXPERIMENT 2: CIB IN GESTURAL TASKS

### Procedure

#### *Preliminary gesture imitation task*

Patient W.S. was asked to copy simple unimanual gestures with her right hand. For this assessment, a 64 × 46-cm piece of paper was placed on the table in front of W.S., so that the centre of the paper was in line with the her right shoulder. The paper was divided by thick black lines into five horizontal sections. A central section of 16 cm defined W.S.’s workspace. Two sections of 8 cm at the left and right edges of the paper defined the examiner’s workspaces, which were separated from W.S.’s workspace by intermediate spaces of 16 cm. The examiner sat alongside W.S., to the right or left. Prior to each trial, it was emphasized that W.S. should make her gestures within her own workspace. The examiner then began a sequence of 20 gestures. The sequence began with the right hand touching the left shoulder, after which the hand was brought to the table as a gesture and then returned to the left shoulder. Patient W.S. was required to copy the examiner’s movements step by step. On each trial, the same gesture was repeated 20 times and was either simple (palm down) or complex (fist down with index and middle fingers in a “V” configuration). Two blocks of four trials were performed, one before the experimental task (see below) and the other after it. In the first block, gesture complexity was manipulated according to a repeating ABBA schedule, with the simple gesture first, and the examiner’s position alternated between trials,



**Figure 4.** Illustrative examples of “instant” closing-in behaviour (CIB), with immediate migration towards the model, followed by tracing of the model contours. These copies were produced by a 60-year-old woman with moderate vascular dementia (Addenbrooke’s Cognitive Examination, ACE score = 74/100; unpublished observation by the authors).

beginning with the examiner to the right of the patient. This trial order was reversed in the second block.

Performance of this task was recorded by a video camera, facing the table. Prior to the experiment, a calibration sheet was laid over the experimental sheet. The calibration sheet was divided into seven sections: W.S.'s central workspace (16 cm) with three further 8 cm sections to either side. On each side, the three outer sections were numbered from 1 to 3, from inner to outer. For each trial, each gesture was scored according to the number of the section that it was made in, with deviations towards the model signed positively and deviations away from the model signed negatively. If the gesture overlapped a dividing line between sections, then the average number of the two adjoining sections was awarded. The average gesture location for each trial was calculated across the 20 gestures, and this value was expressed as a percentage of the maximum possible closing-in score of 3. In addition, each gesture was scored for accuracy of reproduction using the scale of 0–2 (see screening tasks).

#### *Preliminary letter-reading task*

We also checked W.S.'s ability to read random letters of the alphabet, printed individually, at 32-point font, in upper or lower case Arial font on cards (5.7 × 4.3 cm). A first (simple) set of letters was printed normally, whilst a second (complex) set was made more difficult to discriminate by the overlay of a 70% random noise mask. W.S. was able to name letters from the first set without hesitation or error, but letters from the second set only with close scrutiny and occasional errors. This reading task, with two levels of difficulty, was used as a secondary task in the experimental dual task to follow.

#### *Experimental dual task*

In the experimental task, the same set-up and scoring system was used as in the preliminary gesture imitation task. In this case, however, W.S. was required to perform a simple repeated gesture (palm down) from memory, and simultaneously to perform a card-reading task. On

each trial, the examiner sat to W.S.'s left or right and placed 20 cards sequentially in the examiner's workspace on that side. W.S. was required to read each card aloud, whilst simultaneously making the simple palm-down gesture within her central workspace. Prior to each trial, it was emphasized that she should always place her hand within her own workspace, and that she should try to synchronize her gesture with her reading of the card. Two blocks of four trials were performed. In the first block, the complexity of the reading task was manipulated according to a repeating ABBA schedule, with the simple set of letters first, and the examiner's position alternated between trials, beginning with the examiner to the right of the patient. This trial order was reversed in the second block.

## Results

#### *Preliminary gesture imitation task*

In the gesture imitation task (Figure 5), the average quality of W.S.'s gestures was reliably higher for the simple than for the complex gesture (mean rating 1.95 vs. 1.18);  $t(6) = 2.70$ ;  $p < .05$ . In terms of response location, patient W.S. deviated towards the examiner's model gesture in 58/71 movements for the simple gesture (mean deviation = 19%;  $SD = 17$ ), and 78/83 movements for the more complex gesture (mean deviation = 62%;  $SD = 18$ ). A one-way  $t$  test confirmed that the bias towards the model was reliable overall,  $t(7) = 4.12$ ,  $p < .005$ , and an independent  $t$  test found that the bias was reliably greater for the complex gesture,  $t(6) = 3.37$ ;  $p < .05$ .

#### *Experimental dual task*

Figure 6 shows representative responses for each condition in the dual task. W.S.'s gestures deviated towards the letter cards read on all 80 movements for the simple letters (mean deviation = 85%;  $SD = 19$ ) and on 65/80 movements for the complex letters (mean deviation = 48%;  $SD = 59$ ). A one-way  $t$  test confirmed that the average bias towards the letter cards was reliable overall,  $t(7) = 4.15$ ,  $p < .005$ , and an independent  $t$  test, with degrees of freedom adjusted for unequal variances,



**Figure 5.** Representative examples of W.S.'s performance in the gesture imitation task of Experiment 2, showing good quality reproduction with relatively mild closing-in behaviour (CIB) for the simple gesture (upper panels) and poor reproduction with more severe CIB for the complex gesture (lower panels). The examples selected are individual movements in which the CIB score (deviation towards the model) was closest to the mean overall score in the corresponding condition.

found no reliable difference between the average bias for simple and easy cards,  $t(3.59) = 1.20$ , *ns*. In both conditions, there was a strong tendency to show CIB. Indeed, in 97/160 movements overall, W.S. actually placed her hand on top of the cards (her occasional apologies when she did so indicate that she understood this to be an error).

### Comment

W.S.'s motor behaviour, which was characterized by a veering towards the focus of visual

attention, is clearly different from other motor misbehaviours, including "magnetic" (or frontal) apraxia (Denny-Brown, 1958), whereby patients with frontal lesions fail to inhibit their grasp of felt objects, "utilization behaviour" (Lhermitte, 1983), which defines the compulsive use of objects on sight, and "anarchic hand" (Della Sala, Marchetti, & Spinnler, 1994), which is characterized by unwanted, goal-directed actions performed with one hand, often at cross purposes with the other hand.



**Figure 6.** Representative examples of W.S.'s performance in the dual task of Experiment 2, illustrating mild (left panels) and extreme (right panels) examples of closing-in behaviour (CIB) towards the letter cards, for both simple (upper panels) and complex letters (lower panels).

The manual attraction observed in CIB must also be distinguished from “magnetic misreaching”, in which affected patients, required to reach to a target in extrafoveal vision, reach slavishly towards the fixation point (Carey, Coleman, & Della Sala, 1997). This sign, which is characteristic of optic ataxia, has been postulated to reflect a primitive coupling of hand and eye released from inhibition following posterior parietal lobe damage (Milner, Dijkerman, McIntosh, Rossetti, & Pisella, 2002). A similar default coupling may underlie CIB, but in this case its appearance does not reflect a general difficulty in responding away

from fixation, since our screening tests excluded optic ataxic misreaching. Rather the manual attraction may be towards the focus of attention, as required by visual analysis of the model in a copying task, or letter reading in the present dual tasks.

The above proposal is consistent with the view that attention-attracting visual stimuli recruit motor programmes automatically, which must be suppressed continuously to prevent the disruption of ongoing behaviour (e.g., Tipper, Howard, & Houghton, 1998). Subsequent to data collection, we observed informally that W.S.'s manual activity

could also be drawn towards an irrelevant distracting stimulus: Her gesture production migrated towards a strip of reflective paper, crinkled by the examiner's hands. This observation, though anecdotal, suggests that CIB can arise for exogenously created as well as endogenously defined attentional foci.

## GENERAL DISCUSSION

This study compared the compensation and attraction hypotheses of CIB in a patient with moderate AD. The important empirical outcomes were straightforward. In both graphic and gestural copying tasks, a critical role of model complexity was confirmed, with no sign of CIB for very simple stimuli and pronounced veering towards more complex models. This effect of figure complexity replicates previous reports (Lee et al., 2004; Mayer Gross, 1935; Muncie, 1938) but, in itself, is compatible with either the compensation or attraction hypotheses. However, when graphic or gestural production was combined with an unrelated visual discrimination, manual performance migrated towards the visual stimuli, precisely mimicking CIB for copying. This migration cannot be understood as a strategic compensation for visuospatial or memory dysfunction, since the visual stimuli offered no information of relevance to the manual task. Rather, manual performance may be drawn towards any sufficiently absorbing focus of visual attention, as predicted by the attraction hypothesis of CIB.

These results confirm that CIB is a rather general phenomenon, not exclusive to copying tasks, but one that can be elicited, perhaps, by any task requiring visual analysis at one location and motor production at another. The convergent results of the graphic and gestural experiments support the view that a common mechanism underlies the various task-specific manifestations of CIB. Furthermore, we have evidence that common mechanisms may underlie CIB in different populations. We have tested a group of 11 preschool children on an adapted version of the graphic dual task of Experiment 1 and obtained

results that mirrored the performance of patient W.S. exactly (Ambron, Della Sala, & McIntosh, *in press*). In this study, the children attempted to draw horizontal lines whilst simultaneously naming line drawings of animals at the top or the bottom of the page. The children showed pronounced migration towards the animal pictures, as predicted by the attraction hypothesis.

Testing experimentally between attraction and compensation hypotheses is a critical first step in explaining CIB. Having rejected the compensation hypothesis, the next challenge is to further specify the attraction hypothesis. Kwon et al. (2002) have suggested that the manual attraction in CIB is precipitated by a deficiency of executive and/or attentional resources (see also Gainotti, 1972; Lepore et al., 2005). The production of an appropriate copy from a model, in addition to its visuospatial and memory demands, requires the efficient division, or switching, of attention between model analysis and copy production. Task breakdown in CIB could thus plausibly result from the impaired disengagement of focused attention from the model, or from an impaired ability to divide attentional resources between the two subtasks, which might relate to the specific deficit in dual-task coordination that has been found in AD (Baddeley, Bressi, Della Sala, Logie, & Spinnler, 1991; Della Sala, Baddeley, Papagno, & Spinnler, 1995; Logie, Cocchini, Della Sala, & Baddeley, 2004; MacPherson, Della Sala, Logie, & Wilcock, 2007). An important function for executive control would be to inhibit ongoing analysis of the model to allow monitoring of copy production. Evidence that inhibitory functions are impaired in AD is overwhelming (see Amieva, Phillips, Della Sala, & Henry, 2004, for a review).

Inadequate manual monitoring may be more likely when the visual task is complex and would release the default tendency of migration towards the attentional focus. In this context, it should be emphasized that any increase in the difficulty of the visual task should increase the likelihood of CIB, whether the difficulty derives from the task itself or from cognitive factors that render a patient less able to perform a given task. Thus,

we might expect that visuospatial deficits and/or working-memory impairments (as noted in W.S.'s neuropsychological profile) should promote CIB by increasing the subjective difficulty of copying tasks. This mechanism would predict that an overall association between visuospatial impairments and CIB might exist, even though the primary critical factor would be the depletion of executive resources.

The above suggestion is speculative, and considerable work will be required to test and refine the hypothesis. Nonetheless, some initial supportive evidence can be gleaned from the literature. Septien et al. (1992) reported two cases of frontal-syndrome associated with intractable epilepsy, one of whom exhibited CIB as a prominent symptom. Similarly, Hernandez et al. (2002) found that errors (including CIB) in the copying of Luria figures were more frequent in children with frontal lobe epilepsy than in those with temporal lobe or generalized epilepsy. Additionally, Lepore et al. (2005) reported a man with a right frontal infarct who showed CIB in copying geometric figures and mislocated numbers in clock-copying, always in the direction of the model, despite accurate placement when drawing from memory. The authors attributed these effects to a lack of frontal inhibitory mechanisms. CIB in clock-copying was also studied by Cosentino, Jefferson, Chute, Kaplan, and Libon, (2004), who found it to be associated with a higher number of white matter lesions and poorer performance on executive frontal tasks in patients with mild dementia.

Finally, in a group of 43 preschool children, we recently found that graphic CIB was more strongly related to performance on an attentional test battery than on batteries targeting memory or visuospatial functions (Ambron, Della Sala, & McIntosh, 2007). The best unique predictor of CIB was a simple task that required the child to name pictures of animals, but to switch to a clapping response when only the animal's head was presented. This was designated as a test of attention switching, though it is worth noting that the test involved a switch between two responses (and thus inhibition of the inappropriate

response), rather than a switch between spatial locations. We are presently testing whether similar patterns of association can be discovered amongst adults with Alzheimer's disease. We are also testing whether model-directed migration can be induced in normal participants by the addition of attention-demanding secondary tasks to figure copying.

CIB, by providing one route to failure on copying tasks, has long been regarded, by definition, as a form of CA (e.g., Critchley, 1953; Grossi & Trojano, 1999; Mayer Gross, 1935). The present findings show that the phenomenon is not specific to copying tasks, though such tasks may most commonly elicit it in clinical examinations. Whilst the diagnostic label of CA is often taken to imply posterior, especially parietal, neuropathology, CIB might actually be more characteristic of attentional/executive deficits associated with frontal lobe dysfunction.

Manuscript received 4 July 2007

Revised manuscript received 16 January 2008

Revised manuscript accepted 4 March 2008

First published online 16 May 2008

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