Closing-in behaviour and motor distractibility

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This study relates two behaviours, each well documented within its own literature but not previously considered together: closing-in behaviour (CIB) and the effect of visual distractors on reaching. CIB is common in typically developing children, and in adults with dementia, and classically manifests as the tendency to perform graphic copying tasks very close to, or on the top of the model. The effect of visual distractors on reaching has been studied extensively in normal adults. Distractors induce characteristic deviations of the reach, usually away from the distractor, which imply that a competing response towards the distractor is automatically primed, and actively suppressed. It is possible that CIB reflects a failure to inhibit motor distraction, such that the acting hand is attracted automatically to a salient stimulus (the model, during copying tasks). This hypothesis predicts that CIB should be associated with distractor effects during reaching, characterised by veering towards, rather than away from the distractor. We tested this prediction in groups of pre-school children with and without CIB, and in young adults, using task-relevant and task-irrelevant distractors. Both groups of children showed greater veering towards distractors than did adults, implying a lower capacity to inhibit automatic responses. Crucially, this effect was stronger in children with CIB than without CIB when a task-irrelevant distractor was presented. These findings support the idea that CIB reflects a failure to inhibit automatically primed actions towards salient stimuli.

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1. Introduction

In young children (2–5 years), the attempt to copy shapes often results in misplacement of the drawing very near to the model. In extreme cases, the child’s copy may partially or wholly overlap the model. These near- and overlap-tendencies represent more and less severe manifestations of a phenomenon known as closing-in behaviour (CIB). CIB is a normal feature of graphic development, but is also a pathological sign in dementia (Ambron, Allaria, McIntosh & Della Sala, 2009), particularly Alzheimer’s disease (AD) (Ambron, McIntosh, Allaria, & Della Sala, 2009; Gainotti, Parlato, Monteleone, & Carlonagno, 1992). The similarities between CIB in development and dementia may be more than superficial. In both populations, CIB frequency parallels changes in cognitive function, decreasing with cognitive development in children and increasing with cognitive deterioration in AD (Ambron, Allaria, et al., 2009; Ambron, McIntosh, et al., 2009). Studies that have explored the association between CIB and specific cognitive domains have found that CIB is best predicted by impairments of attention, both in patients with AD (Ambron, McIntosh, et al., 2009) and in preschool children (Ambron, McIntosh, & Della Sala, 2010). These patterns support the view that CIB represents a primitive default behaviour, expressed by young children, suppressed in older children and normal adults, and which re-emerges with the reduction of attentional resources in dementia (Gainotti, 1972).

CIB was described in the first half of the 20th century (Mayer Gross, 1935), but it is only within the last few years that it has been explored experimentally. Studies of a patient with AD (McIntosh, Ambron, & Della Sala, 2008) and in preschool children (Ambron, Della Sala, & McIntosh, 2009c) have demonstrated that CIB is not restricted to copying tasks, but may reflect a more general tendency to act towards the focus of attention. In particular, McIntosh et al. (2008) showed that when a patient with AD and CIB was asked to perform a simple action (draw a straight line or perform a simple gesture), whilst reading aloud letters shown at a different location, her actions deviated dramatically towards the letter stimuli. Similar behaviour was observed in preschool children with CIB, who were asked to draw straight lines whilst naming drawings of animals shown at another location (Ambron, Della Sala, et al., 2009c). In both studies, visual attention was directed by the secondary task (letter or animal naming), so the direction of attention was...
relevant to the task goals, albeit irrelevant for the primary movement task. However, McIntosh et al. (2008) noted anecdotally that the actions of their patient with AD could also be drawn towards a salient audiovisual stimulus (a sheet of reflective paper being crinkled by the examiner) that was wholly irrelevant to the task. This suggests that manual attraction can arise through the exogenous capture of attention as well as through the endogenous allocation of attention to a location.

The idea that CIB reflects the failure to inhibit automatically primed actions towards an attended stimulus has obvious resonance with the widely studied influence of visual distractors in reaching. These studies have shown that the spatial path of reaches made by normal adults can be affected by visual attention to distractor stimuli (e.g. Howard & Tipper, 1997; Meegan & Tipper, 1998; Tipper, Lortie, & Baylis, 1992; Welsh, Elliott, & Weeks, 1999). Attention may be drawn exogenously by the onset of task-irrelevant distractors and/or allocated endogenously to task-relevant distractors. However, the direction of the biasing effect can vary, with reach trajectories sometimes veering away (e.g. Gangitano, Daprati, & Gentilucci, 1998; Howard & Tipper, 1997; Tipper, Howard, & Jackson, 1997), and sometimes towards the distractor (e.g. Chang & Abrams, 2004; Chieffi, Ricci, & Carlomagno, 2001; Grierson et al., 2008; Song & Nakayama, 2008; Tipper et al., 1997; Welsh & Elliott, 2004, 2005; Welsh et al., 1999). These directionally opposite effects can both be explained by the same population-coding model of motor responding (Tipper, Howard, & Houghton, 1998; Tipper, Howard, & Houghton, 2000). The core idea is that attention to a distractor entails the preparation of an action towards that location, which is coded within the same population of neurons coding the intended action to the target. The observed reach direction is determined by the vector sum of these two action plans, weighted by their relative activations at the time of the response. An unexpected distractor will elicit a high activation, attracting the response trajectory if the response is made immediately. If the response is not made immediately, or if the distractor was expected in advance, then there may be time for the actor to inhibit the distractor representation, nullifying its influence, or even creating a rebound effect so that the trajectory veers in the direction opposite to the distractor. The behavioural relevance of the distractor may also influence trajectory veering, as it will be more difficult to inhibit a task-relevant distractor than to inhibit a task-irrelevant one. Veering towards the distractor may thus be more likely in the former case, and veering away in the latter (Welsh & Elliott, 2005).

The interpretation of reach trajectories, however, is complicated by other, strategic adjustments that the actor may make (see Tresilian, 1998). For instance, they might treat the distractor as a potential obstacle, even if it is two-dimensional, and veer away from it. If the task requires them to keep the distractor in view (e.g. Howard & Tipper, 1997), then similar manoeuvres may be made to avoid obscuring it with the hand. Alternatively, if the task requires the actor to distinguish the target from the distractor, yet emphasises speed of responding, then an efficient strategy could be to aim initially for an intermediate location and complete the target discrimination online, thereby veering towards the distractor (Tresilian, 1999; Welsh et al., 1999). Such effects may be hard to distinguish from distractor interference. Fortunately, the population-coding model receives less ambiguous support from the study of eye-movements, in which consistent distractor effects are obtained, but alternative explanations based on obstacle avoidance or online target discrimination do not apply. The veering of eye-movement trajectories follows the predictions of the population-coding model precisely, being predominantly towards distractors at short saccade latencies and/or when distractor location is unpredictable, but away from distractors at longer saccade latencies and/or when distractor location is known in advance (Van der Stigchel & Theeuwes, 2006; Walker, McSorley, & Haggard, 2006).

To our knowledge, despite clear conceptual similarities between distractor interference in reaching and the phenomenon of CIB, only one author has proposed that these phenomena could be related (Chieffi et al., 2001, p. 403), and the relationship has never been evaluated experimentally. However, the predictions are very clear. If CIB results from a failure to inhibit automatic responses towards distractors, then veering of reach trajectories towards distractors should be pronounced amongst populations that are prone to CIB (young children and patients with dementia), especially amongst those individuals who actually exhibit CIB. The present study tests these predictions by comparing age- and sex-matched groups of pre-school children with and without CIB, to young normal adults, on reaching tasks performed with task-relevant or irrelevant distractors. Due to immaturity of attentional resources (Backen Jones, Rothbard, & Posner, 2003; Diamond & Taylor, 1996), children should less successfully inhibit distractor-related action plans than should adults, showing greater veering towards distractors, and this effect should be most pronounced for those children with CIB. Our results match these expectations precisely.

2. Materials and methods

2.1. Participants

Twenty one preschool children (8 male, 13 female), aged 3-4 years, were recruited from two day-nurseries. Informed consent was obtained from the legal representatives of the children. On the basis of performance in a preliminary copying task (see below for details), the children were subdivided into a group of ten children with CIB (3 male, 7 female; age: M=50.9 months, SD=9.1), and a group of ten children without CIB (4 male, 6 female; age: M=49.8 months, SD=3.9), with one child excluded due to inconsistent performance. The two child groups were thus well-matched for age [t(18) = -0.34, p > .73], and for sex. Ten young adult volunteers (5 males and 5 females, aged 18–25) also took part. This study was approved by the Psychology Research Ethics Committee, University of Edinburgh.

2.2. Procedure

Children performed a preliminary paper-and-pencil graphic copying task, to test for CIB. They then performed Experiments 1 and 2 in separate sessions of 10–15 min each, on different days. Testing took place at the nursery, in the presence of nursery staff, and the tasks were presented as ‘games’ that the children were invited to play. Adults performed Experiments 1 and 2 only, in a single session. The order of the experiments was counterbalanced within groups.

2.2.1. Preliminary graphic copying task

Children were asked to copy three geometrical figures of increasing complexity: a square, two overlapped squares and a cube. Each figure extended 40 mm × 40 mm and was centred within the left half of an A4 sheet, in landscape orientation. Children were asked to copy each shape in the right half of the sheet, and the examiner indicated the ideal copying space. CIB was scored as present if the copy overlapped with, or came within 10 mm of the model in any part. Ten children confined all copies to the correct space. Amongst children with CIB, ten showed Overlap CIB for all three figures, scrawling on the top of the model (N=6) or tracing the lines of the model (N=4), whilst one child showed Near CIB for two figures (square and cube). Given the less severe and less consistent nature of this last child’s CIB, this child was excluded, yielding a group of ten children with Overlap CIB for all figures, and a group of ten children without CIB for any figure. Overlap CIB was always consistent across all three figures, so there was no indication that this symptom was modulated by stimulus complexity in the present dataset. However, stimulus complexity did affect copy accuracy, with the percentage of children producing unrecognisable copies increasing across the square, overlapped squares and cube stimuli in both groups (30%, 40% and 100% of children without CIB; 50%, 60% and 80% of children with CIB). The high rates of unrecognisable copies suggest that this copying task was very difficult for such young children, which may help account for its high sensitivity to CIB (cf. Ambron, Dellá Sala, et al., 2009c).

2.2.2. Experimental tasks

2.2.2.1. Apparatus. The experiments were designed and run using KInLab software (Culmer, Levesley, Mon-Williams, & Williams, 2009) and were presented on a digitalising tablet laptop (Toshiba Portégé M780); with an active display area of 260 mm × 163 mm. The laptop was placed with the screen facing upwards on a table of suitable height for the participant, who sat with their body midline centred on the long edge of the screen. Participants made reaching responses by moving a
2.2.2. Experiment 1 – reaching with a task relevant distractor. The reaching task for Experiment 1 was designed as a game to appeal to young children, and all participants were given practice using the stylus on the tablet screen before the task began. The stimulus array and trial event sequence is illustrated in Fig. 1. Each trial began with a red dot (10 mm × 10 mm), centred horizontally, 20 mm from the bottom edge of the screen, against a white background. The cursor, indicating stylus position, was a drawing of a farmer (10 mm × 10 mm), and the participant used the cursor to guide the farmer to the red dot, which acted as the trial starting position. When the stylus entered the starting dot, the dot turned green; 500 ms later a red and a black barn appeared on the left and right respectively, near the top edge of the screen. Simultaneously with these two potential targets, a single distractor (red or blue circle containing a line-drawing of a sheep) appeared. The distractor could be in one of three positions: between the two barns, to the left of the left barn, or to the right of the right barn. Targets and distractors were all 20 mm × 20 mm large, and their possible positions were arranged symmetrically around the screen midline, 40 mm apart, in an arc of radius 130 mm from the starting point. The participant was told that the farmer needed to go to work in one of the barns. He did not know which one to go to, but the sheep would help him choose. The task was to look at the colour of the sheep, and to move the farmer to the barn of the same colour as quickly as possible. The cursor left a visible black trail (3 pixels). Once the pen touched the correct target barn, the door of the barn opened and the trial ended with a blank screen 500 ms later.

Each participant was shown the task and given instructions. They were asked to repeat these instructions to ensure that they fully understood the task, and were given four practice trials before the first experimental block. Each participant then performed two blocks of 20 trials, with ten trials per target per block, half of which had the (same-colour) distractor positioned to the immediate left of the target, and half to the immediate right. Trial order was shuffled randomly.

2.2.2.3. Experiment 2 – reaching with a task irrelevant distractor. The reaching task for Experiment 2 was similar to that of Experiment 1, using the same stimulus dimensions and possible positions (see Fig. 1). The key differences were that the cursor was here represented by a clump of grass, a single target (green barn) was presented on each trial, to the left or right of the midline, and a single task-irrelevant distractor (yellow bowling ball) appeared simultaneously with the target. The task was to move the cursor to the start dot and, once the barn appeared, to move the cursor to the target as quickly as possible. The participant was told that there was a hungry cow inside the green barn and that their task was to take the grass to it as quickly as possible, and to ignore anything else on the screen. As in Experiment 1, the cursor left a visible black trail. Once the cursor touched the barn, the barn opened to reveal a cow within the barn, and the trial ended 500 ms later.

Each participant was shown the task and given instructions. They were asked to repeat these instructions to ensure that they understood the task fully, and were given four practice trials before the first experimental block. Each participant then performed two blocks of 20 trials, with ten trials per target position per block, half of which had the distractor positioned to the immediate left of the target, and half to the immediate right. Trial order was fixed and shuffled randomly.

2.2.2.4. Data reduction and analysis. The sampled coordinates of the stylus for each trial were filtered by a dual pass through a second-order Butterworth filter, with a high-frequency cut-off of 10 Hz, and analysed using customised software written in LabVIEW™ (National Instruments). Movement onset and offset were determined by comparison of stylus speed against a conservative threshold of 10 mm/s, and subsequent analysis was restricted to the parsed movement. The focus of interest was on the spatial path of the movements. Movements in which the stylus entered the wrong barn were regarded as errors and deleted (5% of the trials). A polar coordinate transformation was then applied to normalise all movements with respect to the straight line path from the start position to the target position on that trial. The mean deviation from the straight line path was then calculated across all samples for each movement, with rightward deviations coded as positive and leftward deviations as negative.

To provide a fuller description of the reaching movements, the following kinematic variables were also extracted: reaction time (RT) was the duration between the appearance of the green dot and movement onset; movement time (MT) was the duration between movement onset and movement offset; peak speed (PS) was the highest speed reached during the movement; and time to peak speed (TPS) was the duration from movement onset to the time of peak speed. Given the relatively small trial numbers possible with such young samples, we maximised statistical power by entering all the observations for each dependent variable into separate linear mixed-effects model ANOVAs in SPSS, with type III sums of squares. Participants and target location (left and right side of the screen) were entered as random factors, and group (children with and without CIB, and young
and distractor location (left and right of the target) were entered factorially as the fixed-effects of interest.

3. Results

3.1. Experiment 1 – reaching with a task relevant distractor

3.1.1. Mean deviation of reach trajectories

Linear mixed-effects model ANOVA, with participants and target location as random factors, and group and distractor location as fixed-effects, showed significant main effects of group \([F(1.2, 25.52) = 3.42, p < .05]\) and distractor \([F(1.25, 1083.8) = 41.39, p < .001]\), qualified by a strong interaction \([F(1.2, 1083.8) = 6.79, p < .005]\). As shown in Fig. 2, the interaction reflected a pronounced veering of both child groups, but not adults, towards distractors on the right. This was confirmed by splitting the analysis by distractor location, and evaluating the fixed effect of group, with participants and target location as random factors. No differences were found between groups in mean deviation with distractors on the left \([F(1.3, 24.6) = 0.56, p = .57]\), but the effect of group was significant for distractors on the right \([F(1.3, 26.28) = 5.27, p < .05]\). Bonferroni-corrected comparisons confirmed that children with CIB veered significantly more towards a distractor on the right than did adults \((p < .05)\), whilst the comparison between children without CIB and young adults did not reach significance \((p = .08)\), and children with and without CIB did not differ \((p = 1.0)\).

As an additional analysis, we explored whether the distractor-directed deviations were significant, within each group. We therefore conducted equivalent follow-up ANOVAs, this time splitting the data by group. A highly significant main effect of the distractor was observed in both groups of children \((p < .001)\), and the smaller bias towards the distractor in adults was also significant \([F(9.0, 386.08) = 8.13, p < .01]\). Accordingly, all groups deviated towards a task-relevant distractor, but this effect was much more pronounced in children than in adults. Numerically, the effect was strongest in those children with CIB, but a significant difference from children without CIB was not found using a task-relevant distractor.

3.1.2. Further kinematic variables

Means and SDs of kinematic variables are reported in Table 1. A main effect of group was evident for all variables \((F > 6.00; p < .01)\); with pairwise comparisons confirming that the two groups of children produced similar movement kinematics, whilst young adults significantly outperformed children in all aspects of their movement, with faster reactions and briefer movements that reached a higher peak speed at an earlier time \((p < .05\) for all comparisons). There were no main effects of the distractor \((F < 2.15)\) or significant interaction group by distractor \((F < 1.3)\) for any of the kinematic variables.

3.2. Experiment 2 – reaching with a task irrelevant distractor

3.2.1. Mean deviation of reach trajectories

As for Experiment 1, Linear Mixed Model ANOVA showed significant main effects of group \([F(1.03, 26.97) = 7.79, p < .005]\) and distractor \([F(1.03, 1150.2) = 24.26, p < .001]\) qualified by a strong interaction between these factors \([F(1.03, 1150.2) = 11.22, p < .001]\). Similarly to Experiment 1, the differences between groups seemed to emerge with a distractor on the right. As shown in Fig. 3, children with CIB showed a more pronounced deviation towards a distractor on the right than did children without CIB, who in turn showed a stronger deviation than did young adults. This was again confirmed by splitting the analysis by distractor location, and evaluating the fixed effect of group, with participants and target location as random factors. There was no effect of group when the distractor was presented on the left \([F(1.0, 27.22) = 0.60, p = .55]\), but the effect of group was highly significant for distractors on the right \([F(1.0, 26.75) = 14.05, p < .001]\). Bonferroni-corrected pairwise comparisons showed that both groups of children veered more towards a distractor on the right than did adults \((p < .05\) in both cases), and children with CIB deviated significantly more towards the distractor than did children without CIB \((p < .05)\).

An equivalent follow-up ANOVA was conducted, with the data split by group. The main effect of the distractor was significant for children with CIB \([F(1.0, 384.08) = 23.60, p < .001]\) and those without CIB \([F(1.0, 378.2) = 5.63, p < .05]\), but not for adults \([F(7.57, 385.98) = 1.07, p = .30]\). These patterns indicate that adults could adequately inhibit automatic movements towards a task-irrelevant distractor, but children could not, and this inability was significantly more pronounced in children with CIB.

3.2.2. Further kinematic variables

Means and SDs of kinematic variables are reported in Table 1. As for Experiment 1, a main effect of group was evident for all variables \((F > 5.60, p < .01)\). Pairwise comparisons confirmed that
the two groups of children produced similar movement kinematics, whilst young adults significantly outperformed children in all aspects of their movement, with faster reactions and briefer movements that reached a higher peak speed at an earlier time (p < .05 for all comparisons except for the comparison of PV with children with CIB, which did not reach significance, at p = .24). There were no main effects of the distractor (F < 2.00) or significant interactions of group by distractor (F < 2.64) for any of the kinematic variables, except for movement time [F(26.99, 1151.1) = 4.31, p < .05].

4. Discussion

This study explored the relationship between two phenomena, never before brought together experimentally: CIB and the effect of visual distractors on reaching. We have previously proposed that CIB stems from a failure to inhibit automatic actions towards salient stimuli in the workspace (e.g. Ambron, Allaria, et al., 2009; Ambron, McIntosh, et al., 2009; Ambron et al., 2010; McIntosh et al., 2008). This idea suggests a link to the attention-in-action literature, in which trajectory deviations towards distractors are similarly interpreted as incomplete inhibition of automatically cued actions (Chieff et al., 2001). This hypothesised link predicts that populations prone to CIB should also show increased deviation towards distractors during reaching, and that this effect should be most pronounced for those individuals who actually display CIB. Our results confirmed both of these predictions in young children, aged 3–4, justifying the conceptual unification of these phenomena. This outcome supports and suggests further refinements to the attraction hypothesis of CIB on the one hand (Conson, Salsano, Manzo, Grossi, & Trojano, 2009; McIntosh et al., 2008), and a population coding model of distractor effects on the other (Tipper et al., 2000).

Tipper et al.’s population-coding model can explain veering effects towards visual distractors during reaching (or eye movements), but can also account for deviations away from the distractor, or even intermediate results (i.e. no veering). At face value, this might suggest that the model is so flexible as to accommodate all possible outcomes, and is thus unfalsifiable. It is therefore important to demonstrate that there are systematic patterns to the veering effects obtained that make sense within a population-coding framework. As noted in Section 1, short latency responses and/or spatially unpredictable distractors tend to produce more veering towards, whilst longer-latency responses and/or spatially predictable distractors produce more veering away (Howard & Tipper, 1997; Welsh & Elliott, 2004, 2005; Welsh et al., 1999). This is consistent with the assumption that an automatically activated distractor representation is overcome progressively as a function of the time available to develop inhibition. The task-relevance of the distractor may also influence veering, as task-relevant stimuli will be harder to inhibit and may thus induce greater veering towards, than task-irrelevant distractors (Welsh & Elliott, 2005). Our data supported this latter pattern, with greater relative veering towards the distractor in all groups with a task-relevant (Experiment 1) than with a task-irrelevant distractor (Experiment 2). Our study further suggests another systematic pattern that is consistent with a population coding account: groups of participants expected to have fewer inhibitory attentional resources (young children, especially those with CIB) show more pronounced veering towards distractors.

The same prediction should extend to other populations with reduced inhibitory resources; for instance, patients with dementia or frontal lobe damage, children with ADHD, and even cognitively stressed, tired or intoxicated normal adults. Some initial evidence in support of this hypothesis derives from the observation that patients with frontal lobe damage (Aron, Sahakian, & Robbins, 2003) and patients with AD (Simone & Baylis, 1997) show a greater number of errors compared to matched controls in reaching tasks. For instance, these patients have difficulty in inhibiting automatic responses elicited by the distractor, so the reaching movement is often performed towards the distractor rather than the target location.

The distractor effects obtained in our experiments were laterally asymmetrical, with marked differences between groups only for a distractor on the right. Since all participants reached with their right hand, this result can be interpreted as an enhanced effect of the ipsilateral distractor, as already observed several times (Meegan & Tipper, 1998; Tipper et al., 1992; Welsh et al., 1999). In turn, this effect can be understood as each hand having an inherent preference for action towards its own hemisphere, and thus for ipsilateral stimuli to more readily elicit automatic responding (de Jong, Liang, & Lauber, 1994; Fisk & Goodale, 1985; Hommel, 1995; Simon, 1990). Our data suggest that this ipsilateral preference does not manifest with respect to a fixed body midline; in the context of a reaching movement, ipsilateral and contralateral may be defined relative to the principal heading of the reach. The right hand may thus be predisposed to respond in a rightward direction, whether it is currently acting towards right or left hemisphere. Again, some
clear predictions can be extrapolated from this result, for instance that leftward distractors should have a more powerful influence on reaching movements executed with the left hand, and that lateral asymmetries should apply to reaching movements but not saccadic eye-movements, since the eyes operate during saccades as a single non-lateralised effector.

This spatial asymmetry of distractor effects also raises a potential problem for our proposed identification between trajectory veering and the classical phenomenon of CIB, because a similar asymmetry has not to our knowledge been noted for CIB. Indeed, we identified CIB in our present sample of children by requiring right-handed copying of a figure presented on the left side of a sheet, yet the attraction towards this contralateral stimulus was pronounced. This contralateral distraction might derive from the high attentional allocation demanded by the model during copying, which elicits powerful attraction effects. Alternatively, the preferential ipsilateral capture of the hand might not apply during figure copying, for reasons that are yet unknown. An important issue for future research will thus be to establish whether the expression of CIB is modulated by the placement of the model, ipsilateral or contralateral to the responding hand.

With regard to the attraction hypothesis of CIB, our results strongly support the idea that CIB reflects a failure to fully inhibit automatic actions towards salient stimuli (Conson et al., 2009; Kwon et al., 2002; McIntosh et al., 2008). When the distractor was task-relevant, and thus hard to inhibit, reaching movements veered significantly towards it in all groups, but markedly more so in children than in adults, consistent with an expectation of reduced inhibitory resources in this age group. However, when the distractor was made more 'ignorable', by being task-irrelevant, then adults but not children could resist distraction, and a clear difference emerged between children with and without CIB, with the strongest attraction effects in the CIB group. We suggest that CIB is best understood as an uninhibited expression of a natural tendency to act towards the focus of attention, and that immaturity of attentional inhibition in children, or its impairment in patients with dementia precipitates this behaviour.

Distractor-directed veering served as our operational measure of attentional inhibition, consistent with the standard view of this behaviour in the literature (Tipper et al., 1998, 2000). The predicted association with CIB was found, adding to recent evidence for the critical involvement of attentional insufficiencies in the release of CIB in preschool children (Ambron et al., 2010) and in patients with AD (Ambron, McIntosh, et al., 2009). Due to the limitations of working with young children, it was not possible to include additional neuropsychological measures of attention or visuospatial functions for the present cohort. A valuable extension would thus be to establish whether children with CIB and exaggerated distractor-directed veering also show immaturity of attentional functions and/or visuospatial abilities on more standard neuropsychological measures. This would help to illuminate the relation between 'motor distractibility' and attentional control functions more broadly, as well as further testing the specificity of the association between attentional insufficiency and CIB.

The interpretation of the distractor-induced veering during reaching has been the subject of some debate, because alternative explanations are not always easy to exclude. In particular, Tresilian (1998) pointed out that veering away from distractors might arise if the visuomotor system were to treat distractor stimuli as potential obstacles. We tried to mitigate against such effects by making the distractors two-dimensional and equidistant with the targets, and thus unlikely to be treated as obstacles. The fact that our veering effects were largely towards the distractors reassures us that our data were not strongly shaped by avoidance manoeuvres. Nonetheless, a valuable extension of our approach would be to study distractor effects on saccadic eye movements in populations prone to CIB. Saccadic veering would potentially provide an even less ambiguous index of attentional control of action, whilst generalising the findings beyond manual performance. A complementary strategy would be to track the eye-movements of individuals with CIB during classical copying tasks, rather than simply studying the final graphic productions. A generalised attraction account of CIB predicts that the eyes as well as the hand would show pathological attraction, so that individuals with CIB should spend a disproportional amount of time fixating the model. These predictions have been supported in a study which explored eye movement of patients with AD and CIB during a graphic copying task (Midorikawa, Fukatsu, & Takahata, 1996). The gaze of patients with Overlay CIB was “locked” on the top of the model, whilst a “wandering” type of fixation was observed in patients with Near CIB.

Finally, although we have proposed that attentional insufficiency is the key cognitive factor that underlies CIB, we must stress that it is not necessarily the only factor. Classical CIB in graphic copying can manifest as veering towards the model (Near CIB) or as drawing directly on top of the model (Overlap-CIB); and there may be qualitative distinctions between these different manifestations, rather than a simple continuum of severity. A large-scale archival study of 797 patients with AD suggested that, whilst attentional deficits are predictive of Near-CIB, the conversion to Overlay-CIB is additionally associated with visuospatial impairments. On the other hand, a similar archival study which explored the cognitive correlates of Overlay-CIB only found evidence only for group differences in visuospatial abilities (Serra, Fadda, Perri, Caltagirone, & Carlesimo, 2010). The present study does not address the distinction between Near- and Overlay-CIB directly, as only Overlay-CIB was represented within the experimental group. Clearly, it would be of value to assess a larger sample of children on the present tasks, and on additional neuropsychological measures of visuospatial and attentional abilities, in order to explore potential differences between Near- and Overlay-CIB in development. The present demonstration of exaggerated distractor effects in children with Overlay-CIB implies that attentional limitations are an important determinant of this behaviour, even if not the whole story.

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