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Closing-in behaviour

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TITLE: CLOSING-IN BEHAVIOUR: COMPENSATION OR ATTRACTION?

ABSTRACT

*Objective:*Closing-in Behaviour (CIB) defines the abnormal misplacement of the copy performance, which is positioned very closed to or on the top of the model. This symptom is observed in graphic copying by patients suffering from different neurological diseases, most commonly dementia. The cognitive origins of this behaviour are still matter of investigation and research of the last ten years has been focusedon exploring two main accounts of CIB, the compensation and the attraction hypotheses, providing evidence in both directions. While the first account defines CIB as a compensatory strategy to overcome visuo-spatial and/or working memory deficitsduring copying tasks, the attraction hypothesis looks at CIB as primitive default behaviour in which attention and action are closely coupled and movements are performed towards the focus of attention. *Method:*We explored these two hypotheses in a sample of patients with and without CIB, and controls through a series of four experiments: Experiment 1 and 2 tested the attraction hypothesis and respectively the prediction that CIB can be elicited in a non-copying dual task condition loading upon attentional resources or by irrelevant attentional grabbing stimuli. The other two experiments investigated the compensation hypothesis manipulating the distance between model and copying space (Experiment 3) and, the task (copying and tracing) and visual demand (visual copy and memory) (Experiment 4).*Results:*The results support the attraction hypothesis of CIB.*Conclusions:* CIB reflects an impairment of the attention and action system, rather than a compensatory strategy.

Keywords: Closing-in behaviour, attention, visuospatial abilities, memory, copying.

Public Significance: When performing graphic copying tasks, patients suffering from different neurological disorders may place the copy on the top of the model (Closing-in Behaviour). Our work suggests that this phenomenon reflect the tendency to perform an action towards the location of attention.

INTRODUCTION

Closing-in Behaviour (CIB) (Mayer Gross, 1985) is observed when patients are asked to copy geometrical shapes and misplacetheir graphic copying towards the model. The graphic reproduction can either appear abnormally close to the shape to be copied (Near CIB) or even overlap onto the model (Ovarlap CIB). CIB has been classically considered as a manifestation of constructional apraxia (Crichley, 1953;Gainotti, 1972). However, CIB can also appear with relatively spared constructional abilities (Ambron& Della Sala, 2016; Ambron, McIntosh, Finotto, Clerici, Mariani, & Della Sala, 2012b). Furthermore, the phenomenon can occur in other domains, including imitation of gestures (Kwon, Kang, Lee, Chin, Heilman, & Na, 2002; McIntosh,Ambron, & Della Sala, 2008);this finding has reinforced the view that CIB has to be conceived as a general disorder of action involving spatial processing of the movement to be performed.

CIB has been reported in several brain diseases (stroke, carbon monoxide poisoning, corticobasal degeneration, encephalitis, and epilepsy), but it is most commonly associated with dementia (Gainotti, 1972). Although initially considered as a specific symptom of Alzheimer disease (AD) (Gainotti,Marra, Villa, Parlato, &Chiarotti, 1998; Kwack et al., 2002; Kwak, 2004), recent evidence suggest that CIB is equally present in other forms of dementia such as Frontotemporaland Vascular dementia (FTD)(Ambron et al., 2009; Ambron, Allaria, McIntosh, & Della Sala, 2009; De Lucia, Grossi, Fasanaro, Carpi, &Trojano, 2013; De Lucia, Grossi, &Trojano, 2014). Furthermore, the phenomenon has also been observed in patients diagnosed with Mild Cognitive Impairment (MCI) (Ambron et al., 2012b) and in healthyparticipants under some task conditions(Kwack, 2004; Sagliano,D'Olimpio, Conson, Cappuccio, Grossi, &Trojano, 2012).

Two main cognitive hypotheses have been proposed to account for CIB, namely the compensation and the attraction hypothesis (see Ambron& Della Sala, 2016; Trojano & Ganotti, 2016 for a review). The compensation account (e.g., Lee, Chin, Kang, Kim, Park, & Na, 2004) considers CIB as a strategy that patients with visuo-spatial and working memory deficits adopt to perform a copying task. The tendency to perform the copy close to or on the top of the model would be functional to reduce the distance between the model and the copy space, decreasing the load on visuo-spatial and memory functions.The attraction account of CIB(Kwon et al., 2002; McIntosh et al., 2008) interprets CIB as resulting from a primitive organization of the motor system in which attention and action are closely coupled, so that the movement is attracted and

executed towards the focus of attention. Therefore, CIB may represent a primitive default tendency of the motor system to respond to attention grabbing stimuli. This tendency would be inhibited in normal adults due to high cognitive and executive resources, but reappears in patients as consequence of brain damage andreleased by attentional and/or executive deficits (Ambron et al., 2009; McIntosh et al., 2008).

The attraction account predicts that CIB can be elicited in healthyadults under certain task conditions, with high demands on attention and/executive functions (McIntosh et al., 2008). This prediction has been sustained in a few studies. The tendency to perform the graphic copying towards the model was elicited in a sampleof young adults when the attentional load of the graphic copy was increased in adual task condition(Saglianoet al., 2012).The attraction account has been supported also by studies with both AD (Ambronet al., 2009; Grossi et al., 2014) and FTD (Ambron et al., 2009; De Lucia et al., 2013; Grossi,De Lucia, Milan, &Trojano, 2015) patients. In these studies, the emphasis has been placed to attention and executive deficits as primary causes for the presence of CIB (Ambron et al., 2009; De Lucia et al., 2013).The co-occurrence of CIB with dysexecutivesymptomssuch as the environmental dependency syndrome (Grossi,De Lucia, &Trojano, 2015) further supports the possible involvement of executive dysfunctions in the nature of this phenomenon.

On the other hand, exploring the cognitive nature of CIB in AD, Serra, Fadda, Perri, Caltagirone, &Carlesimo, (2010) found supportive evidence for the compensationhypothesis of CIB, showing that among different cognitive tasks, only visuo-spatial deficits allowed distinguishing between patients with and without CIB. However, the experimental manipulations used in these studiesconcerned variables such as the distance between model and the copy or the complexity of the model (Kwon et al., 2002; Lee et al., 2004). These variables do not allow disentangling between the two hypotheses of CIB, as the demand of both attentional and visuo-spatialresources is enhances bythese manipulations (for a discussion see Ambron& Della Sala, 2016; Trojano & Ganotti, 2016).

In the current study, patients with and without CIB, and age-matched controls were presentedwith four experiments devised to investigate the nature of CIB and to test the different predictions of the attraction and the compensation hypothesis.*Experiment 1*aimed at replicating and extending to a group study the results previously observed in a single case study of a patient affected by moderate AD, who showed CIB in both

graphic copying and imitation of gestures(McIntosh et al., 2008). This patient was presented with two dual tasks conditions, in which a simple movement (drawing a straight line or performing a simple gesture) was associated with a secondary task (letter reading task). In both dual tasks, this patient performance veered markedly toward the location of the attended letters (top or bottom of sheet in the line drawing task; right or left of the table surface in the gesture performance task). This evidence is supportive of the attraction hypothesis of CIB (Lee et al., 2004), which conceives CIB as a bias towards the point of attention rather than a compensatory strategy functional to the copying task.In the present study, we focused on the graphic dual task.

Experiment 2tackles specifically the attraction hypothesis and its main tenet that CIB reflects a primitive organization of the motor system to acttowards attentional grabbing stimuli (Ambron,Della Sala, & McIntosh, 2012a). Here we tested whether line drawings of patients with CIB would veer towards task irrelevant but salient stimuli presented at the top or at the bottom edge of the drawing sheet.

The last two experiments were specifically focused on the compensation hypothesis.

In Experiment 3, participants were presented with a series of copying tasks in which we manipulated the distance between the model and the copying space. The novelty of our manipulation lies in that thetwo spaces were framed into two boxes and placed within a grey background, which emphasised their separation. The compensation hypothesis predicts a larger bias towards the model when the distance between these two spaces is larger.Experiment 4 tested whether the copy of laterally extended geometrical stimuli protect from the tendency to veer towards the model in this sample of patients with CIB and whether this tendency increases when copy is associated with a dual tasks condition loading upon verbal working memory, as previously observed (De Lucia et al., 2013). As previously discussed, this experiment does not aim to distinguish between the two hypotheses of CIB, butsimply assess whether the general increase of the task demand enhances CIB tendency.

Finally, Experiment 5tested a further principle of the compensation hypothesis of CIB, known as 'coordinate transformation'(Ogawa & Inui, 2009):CIB would result from representational deficits and from the difficulty in creating an egocentric representation of the model, as required in copying task. To compensate for these difficulties, patients with CIB would convert copying into tracing. This account has been proposed in a functional magnetic resonance imaging study (Ogawa & Inui, 2009), but it has never

been tested in patients. Patients with CIB should perform as well as controls in both tracing conditions, such as when they were asked to trace over the lines of the model (visual tracing) or to retrace over path where the model was previously presented (memory tracing). On the contrary, patients with CIB should differ from controls in conditions whereby the drawing trajectory and the model position are apart (Ogawa & Inui, 2009). Specifically, a tendency of the graphic copying to veer towards the model should be observed in both visual copying and in drawing from memory. In this latter condition, the compensation hypothesis predicts that although the model is not visually presented, patients with CIB would show a tendency to reproduce the model where it was originally presented (top or bottom edge of the paper) in the attempt to convert copying into a tracing task. On the contrary, the attraction hypothesis predicts that CIB should emerge in graphic copying, but this tendency should be reduced in the drawing from memory condition, when the model is not present on the drawing sheet.

Closing-in Behaviour (CIB) (Mayer Gross, 1985)Across all fourexperiments, the results show a consistent support for the attraction, over the compensation hypothesis, and support the view that CIB represents a movement bias towards the focus of attention.

MATERIALS AND METHODS

Participants

The aetiology was not relevant in this study, as our aim was to study CIB. Therefore a heterogeneous group of 18 brain-damagedpatients with and without CIB was recruited for the purpose of this study from the Rehabilitation Department of S. Antonio Abate Gallarate Hospital, Italy.

Presence of Near (more than 1cm from the model) or Overlap CIB was assessed by means of the pentagons copying task of the MMSE and the copy of three geometrical shapes, varying in complexity (square, overlapped squares, cube).As the main focus of our paper was to test between the two competing hypothesis of CIB rather than to test differences between CIB types, patients were divided into two groups according to the presence/absence of CIB in at least one graphic copying task.The CIB group was composed of nine patients (sixprobable AD, two focal right hemisphere damage and one encephalitis). The no-CIB group was also composed of nine patients (three with AD, one FTD, one MCI,two focal right hemisphere damage, one focal left hemisphere damageand one TBI).In the CIB group, four patients showed Near CIB and fiveOverlap CIB. Furthermore, the presence of constructional apraxia was recorded if at least one of patients' drawings was judged as unrecognizable. Using this criteria constructional apraxia was observed in 7/9 patients with CIB and 5/9 patients without CIB.

A group of 16 healthy adults without CIB, matched with the patients for agewere also recruited to the study.

NEUROPSYCHOLOGICAL ASSESSMENT

Patients and controls were tested with the Italian version of the MMSE (Measso et al., 1993). In addition, the patients underwent a comprehensive neuropsychological battery (see Table 1). Patients were also assessed for the presence ofOpticAtaxia and Spatial Neglect. For Optic Ataxia assessment, patientswere asked to fix the examiner nose and to reach for peripheral targets (a pen presented in examiner's left or right hand).

Ifpatients were unable to keep fixation, the trail was repeated. If this behaviour remain consistent and patients were classified as

Signs of Optic Ataxia weredetected in two patients with CIB and one without CIB. Neglect was assessed using the Star Cancellation test (Wilson et al., 1987). The presence of Spatial Neglect was observed in two patients with CIB and two patients without CIB. Furthermore, the examiner was instructed to report any evidence of utilization behaviour, but none of the patients showed the tendency to use the objects present on the testing desk.

----- Insert Table 1 about here -----

EXPERIMENTAL TASKS

General Experimental Procedure

Participants were presented with four experiments in one or more testing sessions depending on their tiredness and willing to participate. The order of the experiments was fixed for all participants.
All participants signed an informed consent and the present study was approved by the Hospital S. Antonio Abate Gallarate, Varese, Italy.

Data extraction

Throughout the four experiments, weapplied the scoring procedure used ina previous study (Ambron et al., 2009). We measured the average deviationof the participants' line drawingfrom the ideal line connecting the starting point and the right edge of the paper estimated for the horizontal coordinate considered from the start position for each successive rightward increments of 10 mm until the right hand edgeof the paper or until the drawn line was no longer present. Positive scores indicated an upward drift of the drawing, whereas negative deviations reflected a downward drift of the line drawing.

Data analysis

Due to the heterogeneity of our sample and to account for the possible differences between individuals, data were analysed using linear mixed models using R (version 3.3.0) with LMER and languageRpackages.

To control for the variability across individuals, participantswere inserted as random factors in the model. In all experiments, groups (patients with CIB, patients without CIB, and controls) were inserted as fixed factor in addition to the other variables of interest. Furthermore, as described in a previous paragraph the aetiology was not relevant for this study and we were interested in testing the phenomenon *per se*. However,to control for the possible effects of the diagnosis and constructional apraxia, this factor was also inserted in all the models as main effect.

Additional factors inserted in the model and specific for each experiment were: for Experiment 1 and 2, position (top and bottom); for Experiment 3 position (near and far); and for Experiment 4, position (top and bottom), condition (copy and tracing) and vision (visual and memory). Factors and interactions were entered into the model in stepwise manner and only factors, which contributed significantly to the model fit (tested with ANOVAs) were kept in the final model.

EXPERIMENT 1: DUAL TASK (DIGITS NAMING)

Material and methods

In this dual task experiment, we used a revised version of the task previously in the single case studyof a patient with AD (McIntosh et al., 2008) and combined a straight line drawing task with a digits naming task. Patients were asked to draw a straight line from a starting position (0.5 cm) centredverticallyon a sheet of paper (2 cm from the left edge) to theright-hand edge of the paper. Simultaneously to this drawing task, participants were asked to attend to and namea series of 15 digits (font size 20) printed across the top or bottom edges of the same paper (space between the digits about 1.3 cm; distance to the left edge 3.8 cm -see Figure 1). The task comprises 8 trials (4 with the digits presented on the top and 4 at the bottom) in two blocks of 4 trials in which the position of the digits was manipulated according to an ABBA scheme, starting with the digits presented at the top.

----- Insert Figure 1 about here -----

Results

The final model included bothfactors position (top and bottom) and groups (CIB, noCIB, controls) as well as their interaction.The line drawings of patients with CIB were markedly displaced towards the digits, $t(264)$=8.5, p<0.001, but this tendency was not observed in patients without CIB, $t(264)$=0.7, p= 0.4, or in controls,$t(264)$= -1.0, p= 0.2 (see Figure 1).Furthermore, when the digits were presented at the top, patients with CIB showed a larger bias towards the location of digits than patients without CIB, $t(263)$=-4.7, p<0.001,and controls, $t(36)$=-6.4, p<0.001.Also, in this condition, controls showed a larger bias than patients without CIB, $t(264)$=2.4, p=0.01. When the model was presented at the bottom, patients with CIB showed a larger bias towards the digits than patients without CIB,$t(264)$=3.0, p=0.002, but similar performance to controls, $t(265)$=0.10, p=0.91. Furthermore, the line drawings of patients without CIB veered more towards the digits than controls, $t(264)$= -2.4, p=0.014.

Comments

This experiment tested the competing hypothesis of CIB. When patients with CIB were asked to draw a straight line in the centre of the page and to name at the same time a series of digitspresented on the top or bottom edge of the drawing sheet, they showed a distinctive tendency to draw towards the position of the digits. This result reinforces the attraction over the compensation account, which does not predict the appearance of CIB in a task not involving graphic copying. This result stresses the interpretation of CIB as a general disorder of action in which movements are attracted and directed towards the focus of attention (McIntosh et al., 2008).

EXPERIMENT 2: IRRELEVANT DISTRACTOR

Material and Methods

This experiment investigated whether the simple presence of an irrelevant stimulus with high perceptual salience could elicit CIB. As for the previous experiment, participants were asked to draw a straight line in

the centre of an A4 paper from a starting position (a 0.5 cm segment) centredverticallyon the left edge of the A4 paper (2 cm from the edge). In this task coloured pictures (about 12 cm x 3 cm) of famous moviestitles (e.g., Casablanca) were printed on the top or bottom edge of the paper and placed at the right corner (see Figure 2). In each trial, the examiner placed a rectangular blank strip of paper on the top of this stamp and removed it progressively as participants were drawing of the line. Participants were explicitly asked to concentrate on the line drawing and not to pay attention to the movie titles. Same number of trials (n=8)[1]and procedure of Experiment 1 were used in this experiment.

----- Insert Figure 2 about here -----

Results

The best regression model included both position (top and bottom) and groups (CIB, noCIB and controls), and their interaction. Changes of the line drawing according to the irrelevant stimulus position were observed for both CIB, $t(233)$=2.8, p=0.005 and noCIB groups, $t(233)$=-3.3, p=0.001 (see Figure 2).The tendency to draw towards the irrelevant distractor as also observed in the control group but it did not reached significance, $t(233.1)$=1.5, p=0.12.When the irrelevant stimulus was presented at the top edge of the sheet, patients with CIB showed a larger bias than controls, $t(31)$=-2.7, p=0.009, and marginally than patients without CIB, $t(37)$=-1.8, p=0.07. When thestimulus was presented at the bottom edge of the page, patients with CIB showed an upward drift that was greaterthan controls,$t(31)$= -2.2, p=0.03,and than patients without CIB,$t(35)$= -2.0,p=0.04. Patients without CIB differed from controls only marginally when the stimulus was presented at the top edge of the paper, $t(35)$=-1.8,p=0.07, while similar performance was observed when the stimuli were printed at the bottom edge,$t(33)$=1.3, p=0.17.

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[1]One patient with CIB and one without did not perform one trial (total of 7 trials each)

Comments

The results of this experiment further corroboratesthe attraction account of CIB by showing that patients with CIB are prone to draw towards salient stimuli even if they are irrelevant for the manual task. Similarly, children with CIB have shown to bemore prone than children without CIB to respond towards attention capturing stimuli, both when attention is endogenously directed towards these stimuli, and when the secondary task is irrelevant to the on-going action and involves more automatic and exogenous attention capturing mechanisms (Ambron et al.,2012a). The present results suggest that similar mechanismsare at play also in older patients with CIB. As for Experiment 1, the observation that a smaller tendency to draw toward the irrelevant stimulus can be elicited also patients without CIB and normal controls corroborates further the hypothesis that CIB may reflect an extreme manifestation of a primitive tendency in coupling attention and action (Ambron& Della Sala, 2016).Furthermore, these results support the observation that a small tendency to respond towards attentional grabbing stimuli can be elicited also in patients without CIB or healthy adults (Sagliano et al., 2013; Ambron et al., 2012a) and support further the notion that CIB might reflect a default tendency to act towards attention (Ambron et al., 2012a; McIntosh et al., 2008).In other words, the present task loading on attention may have elicited and enhanced the coupling between attention and action across groups. However, in support of the view that CIB is an extreme manifestation of this attention and action coupling, the magnitude of the attraction towards the focus of attention was higher in this group.

EXPERIMENT 3: COPYING SPACE MANIPULATION

Material and Methods

In this experiment, we manipulated the distance between model and copy spaces, so that in one condition the model and copy spaces were in close proximity (Nearcondition), whereas in another condition they were apart (Far condition). In both conditions, patients were asked to copy Luria's figures composed of 15 units (square, triangle and arch arranged in prefixed sequences) of 1 cm x 1 cm each, joined by lines of 0.5 cm (overall length of the figure: 23 cm x 1 cm). These shapes were placed centrally within a white rectangular box (24.5 cm x 3 cm) spaced 1.5 cm from the top edge of the sheet of paper. The copying space was also

delimited within a white rectangular box and a black line (0.5 cm long) indicating the starting point for the copy (see Figure 3). This line was vertically aligned with the starting point of the model and was spaced from the edge of the box (8 mm) (see Figure 3. The background of the paper was grey, so that the boundaries between copy and model were overt. In the Near condition, the rectangular box for the copy was placed in closed proximity to the box where the model was presented (0.1 cm distance), whereas in the Far condition, the space between the two boxes was of 8.8 cm.Participants performed two blocks of four trials each[21]in which the conditions were alternated in an ABBA design, with the Nearcondition first.

For the patients' groups, the quality of the copy was evaluated only in Experiment 3as the total number of elements reproduced for each picture (maximum score 15).This judgment was not carried out for one patient with CIB as these data were no longer available at the time of this assessment was carried out.

----- Insert Figure 3 about here -----

Results

The best regression model included the factor position (Near and Far) and the interaction between position and groups (CIB,noCIB, controls).A modulation of theline drawing depending on the model position, with alarger tendency to deviate towards the model in the Near than Far condition, was observed in patients with CIB, $t(230)= -5.0$, $p<0.001$, without CIB, $t(230)=3.0$, $p=0.002$, and marginally in controls,$t(230)= -1.8$, $p=0.06$ (see Figure 4). However, overall the difference in the performance between groups did notreached significance level neither in the Near or Far condition. For the accuracy of the line drawing, the final model included only the position as significant fixed factor ($p<0.001$ compared to subjects only random factor model), as both patients groups showed an improvement in the accuracy in the Near than Far condition (noCIB: Near $M= 14.6$; Far $M= 14.2$; CIB: Near $M= 12.2$, Far $M= 11.8$).

Comments

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[2]For fatigue, one patient with CIB and one without did not perform one trial (total of 7 trials each), and one patient with CIB performed only one block of 4 trials.

This experiment tested the compensation account of CIB manipulating the distance between the model and the copy spaces. If the tendency to draw toward the model was higher in the Near than Far condition, this behaviour did not distinguished patients with CIB specifically, but it was observed across the three groups. The outcome from this experiment is not so surprising as previous studies showed that the magnitude of CIB does not vary according to the distance in either graphic copying (Lee et al., 2004) or imitation of gestures (Kwon et al., 2002).

The compensation account predicts that patients with CIB would show a copying bias towards the model when the copying space and model space were set apart(Far condition) as the demand of visuo-spatial and working memory would be higher in this condition. On the other hand this hypothesis would predict an increase in the accuracy when the model is closed to the copying space.Contrary to these predictions, accuracy did not change acrossconditions and the performance of patients with CIB was akin that of patients without CIB. These findings could hardly be interpreted in term of the compensation hypothesis.

A possible explanation that changes between near and far conditions were observed only in CIB patients is that the manipulation of the model and copy space may interact specifically with CIB. It is possible that the close proximity of these spaces in the near may trigger the attraction towards the model more than the far space, but the clear distinction of the copy spacesthrough the the boxeshave moderated this tendency. Thestructure of our task may have favoured the disengagement of the attention from the model location and its reorientation towards the copying space, reducing the attraction towards the model in CIB patients. However, as in this experiment participants were asked to copy a lateral extensive geometrical figure, an alternative interpretation is that the copy of geometrical stimuli may protect the motor action of drawing from deviation towards the shape in this sample of patients with CIB. To test this hypothesis, we asked participants to perform a copying task similar to the one used in Experiment 3 without providing a clear delimitation of the copying and model spaces (i.e. the boses) (see Experiment 4).

EXPERIMENT 4: THE EFFECT OF DUAL TASK (PRELOAD- DIGIT SPAN)

Material and Methods

This experiment aimed at specifying the results from Experiment 3 and tested whether the copy of laterally extended geometrical stimuli, like Luris's figures, may reduce the tendency to veer towards the model in our sample of patients with CIB. In addition, this experiment tested whether a secondary task may affect the magnitude of CIB (De Lucia et al., 2014). Participants were asked to perform a graphic copying task in two conditions: simple copy and dual task. In this latter condition, the secondary task was a verbal working memory task. Participants were presented with a series of digit of the length of their digit span and they were asked to hold it in memory while performing the drawing task. Once completed their drawing they were asked to recall the digits in the same order as presented by the examiner.

The model-shapes were simplified versions of Luria's figures presented along the top or bottom half (1 cm from the edge) of an A4 paper presented in landscape orientation (3 cm distance from the left edge) (see Figure 4). This laterally extended shape was composed of 14 units (7 squares and 7 triangles) arranged in fixed sequences. Each of these elements was 10 mm long and 10 mm high, and the line connecting adjacent elements was 5 mm long. The starting point of the copy was specified by a 5 mm line centred vertically (8 cm below the model) 3 cm from the left edge of the page. Patients were asked to perform the graphic copying starting with the pen placed on the top of the starting point. Each participant performed two blocks of four trials in which the model position was alternated using ABBA design, with the model on the top first. The copy condition (single or dual task) was alternated between trials starting with the simple copy first.

Results

As shown in Figure 4, patients with CIB showed the tendency to perform the copy drawings towards the model in both simple copy and dual task conditions, and this tendency was similar in both conditions. On the contrary, a general tendency towards the top of the page was observed in both patients without CIB and in the control group. This upward drift of copy drawing was similar across conditions and did not change as function of the model position. Linear-mixed model analysis confirmed these observations, as the final

model included the main effect of position (top and bottom) and the interaction between position and groups (CIB, noCIB and controls). A significant effect of the model position was observed only in patients with CIB, $t(231)=-8.8$, $p<0.001$. Patients with CIB showed a larger deviation towards the model than the other two groups when the model was placed at the bottom, $t>3.8$, $p<0.001$, and a larger deviation towards the model than patients without CIB when the model was at the top, $t(51)=-2.1$, $p=0.03$.

Comments

This experiment followed up the results of Experiment 3 and investigated whether copying laterally extended geometrical shapes protects motor action from deviating towards the model. Contrary to this interpretation, but in line with the definition of the phenomenon, patients with CIB showed a strong tendency to deviate towards the model when copying Luria's figures. This tendency was not observed in the other two groups, who showed instead a general upwards drift of the line drawing towards the top of the page. This tendency to deviate towards the top of the page can be disentangled from CIB, as it does not change as a function of the model position. These observations reinforce the idea that laterally extended geometrical figures can be a good tool to test for the presence of CIB, but stress the importance of varying the position of the model to distinguish CIB from common drawing biases (Ambron & Della Sala, 2017)

In addition, this experiment also tested whether CIB increases as a function of the general cognitive demand of the task. Specifically, in this experiment the graphic copying task was presented either as a single task or associated with a verbal working memory task. Contrary to previous evidence with patients with Alzheimer's disease (De Lucia et al., 2014), the tendency to veer towards the model did not increase in the dual task condition in patients with CIB or in the other groups. There are different explanations which can account for the discrepancy observed between the studies. First, in the present study, we used a secondary task with verbal working preload, as participants were asked to rehearse the digits during the copy execution and to repeat them aloud only when the drawing task was completed. On the contrary, in De Lucia et al.'s (2014) study the secondary task (to count) was performed during the overall execution of the drawing task. The preload of verbal working memory might not have been enough to enhance the magnitude of CIB in our sample. On the other hand, the direct execution of the secondary task in conjunction with the copying tasks might have facilitated the increase of CIB tendency in the dual task condition. An alternative explanation is

that tendency to veer towards the model was already quite remarkable in our sample, so that it would be hard to further enhance it in a dual task manipulation. This explanation, which has also been used by De Lucia et al.'s (2014) to support a lack of CIB modulation under dual task condition in VaD, is plausible taking into account that in our sample five out of nine patients presented the most severe form of CIB (i.e., Overlap CIB).

EXPERIMENT 5: COORDINATES TRANSFORMATION

Material and Methods

This experiment tested whetherCIB is the result of coordinate transformation deficits, which hamper the ability to create a mental representation of the model. Participants were presented with four different experimental conditions, modified from a previous study in young adults (Ogawa & Inui, 2009). These were: visual tracing, memory tracing,visual copy, and memory copying.

As shown in Figure 5,in the all the conditions, participants were presented with wavy patterns (24 cm long), composed of small or larger curves, and presented either at the top or bottom edge of the A4 paper(1.5 cm distance from the edge). We used this type of shapes rather than Luria's figures, as they are simpler to reproduce but at the same time more difficult to remember using verbal strategies.

In the *visual conditions,* the model was visually presented for the entire duration of the task while in the *memory conditions,* the wavy pattern was presented for the time that participants needed to memorize it and then removed (5 to 10 seconds). Immediately after, a new blank sheet of paper was presented with a starting point marked on the paper. The main difference between tracing and copying conditions was in the location of the starting point (black dot) of participants' drawing. In the tracing conditions, the starting point was placed on the right hand side of the paper in correspondence to the beginning of the model (top or bottom edge). Therefore in the *visual tracing*, as the model was present and the starting point was overlapped to the starting point of the model, participants task was tracing over the model (see Figure 5). In the *memory tracing,* the model was removed during drawing, but participants were required to draw from memory at the same location as the model was initially presented (top or bottom half of the paper). Hence, they were asked

to start their drawing from a black dot placed on top right or left hand side in correspondence with the starting point of the model previously presented. In the *visual copying* the model was also presented at the top or bottom edge of the paper, but the starting point of the copy was centred vertically and aligned on the left edge of the paper (3 cm distance from the edge). Similarly in the drawing from from memory condition (*memory* condition), participants were asked to draw the wave from memory, but to use a dot centred vertically and aligned on the left edge as starting point of the copy. In other words, in the tracing conditions there was spatial correspondence between the copy and model space, both being either at top or bottom edge of the sheet of paper, whereas in the copy conditions copy (centre of the sheet) and model spaces (top or bottom edge of the sheet) were distinguished.

Each participant performed four blocks of eight trials: the first two with the model presented at the top and the other two with the model at the bottom. In the first block, the conditions were presented in the following order: visual tracing, visual copying, memory tracing and memory copying. This order was then reversed in the second block.

Results

Due to the different scoring procedures between tracing and copying, we run two separate mixed linear models analyses for each of these conditions (see Figure 4a representation for the results of both analyses). For tracing, the final model incorporated only the position as factor ($p<0.001$ compared to subjects only random factor model): participants line drawings deviated more towards the bottom when the model was placed at the top (*M*= -3) and more towards the top when the model was presented at the lower edge of the paper (*M*= 6.7), *t(236)*= -7.3, *p<0.001*.

In *visual copying*, patients with CIB showed a line drawing bias model directed, *t(229)*= -7.7, *p<0.001*, and this bias was larger than patients without CIB, *t(95)*= -2.5, *p=0.01*, and than normal controls, *t(47)*= -2.4, *p=0.01*, when the model was at the top, but similar performance was observed with the model at the bottom. Interestingly an effect of the position indicating a bias towards the model was also elicited in patients

without CIB, $t(229)= -5.8$, $p<0.001$, and controls, $t(229)= -6.6$, $p<0.001$, but no difference was observed between these two groups.

In the *memory copying* condition, the groups of patients, $t(229) > 3.8$, $p< 0.001$, and marginally the controls, $t(229)=-1.8$, $p= 0.06$, showed a bias towards the position where the shape was previously presented. There were no significant differences between groups with the exception of a larger upward line drawing drift in patients without CIB than controls when the model was at the top, $t(47)=-1.9$, $p=0.06$. Furthermore, while patients without CIB showed a significant difference between copy and memory conditions when the model was at the top, $t(229)=2.6$, $p=0.009$, and at the bottom, $t(229)=4.5$, $p<0.001$, patients with CIB, $t(229)= -1.9$, $p=0.04$, and controls, $t(229)= -5.1$, $p<0.001$, showed this difference only when the model was at the bottom

Comments

The last experiment tested a further specification of the compensation hypothesis, which identifies impairment in the development of an egocentric representation of the model as the core deficit of CIB. This ability is crucial to reproduce a shape at a different spatial location from the model and to distinguish copying from simple tracing. To overcome the breakdown of co-ordinate transformation, patients with CIB would convert copying into tracing, reducing the distance between the drawing trajectory and the model (Ogawa & Inui, 2009). In line with this hypothesis, we found that patients with CIB performed as the other groups in both *visual tracing* condition, supporting the idea that the motor impairment in CIB would affect higher level of motor control mechanisms, but lower grapho-motor mechanisms would be preserved in these patients (De Lucia, Trojano, Vitale, Grossi, Barone, &Santangelo, 2015; Ogawa & Inui, 2009). On the other hand the coordinate transformation hypothesis predicts that in the *memory tracing* condition patients with CIB should to be similar to the other groups since the original position of the model and the drawing space overlap, with the consequent reduction of coordinate transformation requirement.

However, this hypothesis specifically predicted that patients with CIB would show a similar performance in *visual copying* and *visual memory* conditions, as they would find advantageous retracing the same path of the model even when this stimulus was no longer visible, as in the memory condition. The results of this

experiment support these predictions partially, as the performance of both patients with CIB was similar in copying andmemory conditions with the model at the top. On the other hand, this tendency was also observed in normal controls and patients without CIB. In this last group, the tendency to draw towards the previous location of the model was accentuate in the memory condition as demonstrated by the increase of the model directed line drawing bias in memory compared to the copy condition. Furthermore, across conditionssimilar performance was observed between groups suggesting that the tendency to retrace the path of the model was not a specific strategy of patients with CIB.Taken together, these results speak against the coordinate transformation hypothesis, though they provide additional support for the attraction hypothesis.

GENERAL DISCUSSION

This study explored in some depth the two competing hypothesis of CIB, through a series of experiments designed to tap different aspects of the compensation and attraction hypotheses. Taken together the resultssupport the attraction over the compensation account of CIB.The outcome from Experiments 1 and 2 directly complied with the predictions of the attraction account. Experiment 1 showed that CIB is a general disorder of action in which the movements are attracted towards the focus of attention.Experiment 2 extended these observations to task-irrelevant stimuli. It specifically supports the hypothesis that patients with CIB might be more prone to respond and act upon attentional grabbing stimuli, not only when attention is voluntary directed towards a specific location, but also when exogenous attentional mechanisms are involved (see also Ambron et al., 2012). In addition, the attraction hypothesis received indirect support by the findings from Experiments 3 and 4, designed to test the compensation (and the coordinate transformation) account.

Finally,attraction hypothesis is corroborated furtherby the cognitive profile of the patients entering the study. In line with previous literature (Ambron et al., 2009; 2012; De Lucia et al., 2013; 2014; Grossi et al., 2014), the cognitive profile of patients with CIB is characterised byattentional and/or executive deficits. The only task that differed between patients with and without CIB was the Frontal Assessment Battery. This battery of tasks is specifically designed to test executive function and inhibition, and has been previously shown to predict CIB in patients with Mild Cognitive Impairment (Ambron et al. 2012b), but it has also been associated to CIB in patients with dementia (De Lucia et al., 2013). These resultsis also in line with

hypothesis of a frontal /executive nature of CIB (see Ambron & Della Sala, 2017; Trojano & Ganotti, 2016 for review on this topic) and the observation that CIB is associated with atrophy inorbito-frontal cortex in patients with probable AD (Kwon et al., 2015).

It is worth mentioning that we did not tested for possible differences between Near and Overlap CIB and a future direction should be to investigate whether similar mechanisms can account for both types of CIB.3

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Table 1. Demographic and neuropsychological measures (Means and Standard deviations) of patients with
and without CIB and controls.

	CIB	NoCIB	Controls
	N=9	*N*=9	*N*=16
Age	66.56 (11.29)	63.56 (15.15)	65.06 (11.22)
Education	7.89 (4.37)*	9.67 (4.72)	12.25 (2.86)
MMSE [1]	19.77 (5.3)**#	25.13 (4.09)^	29.00 (1.51)
Frontal Assessment Battery [2]	9.00 (1.91)# *n*=7	13.00 (3.78) *n*=8	
Trail Making Test A [3]	219.50 (152.21) *n*=6	157.33 (181.09 *n*=9	
Trail Making Test B	326.50 (103.94) *n*=2	281.86 (138.41) *n*=7	
Trail Making Test B-A	245.50 (95.46) *n*=2	204.57 (112.69) *n*=7	
Spatial short term memory (Corsi Blocks) [4]	2.57 (1.40) *n*=7	3.44 (1.81) *n*=9	
Digit Span[5]	4.00 (0.76) *n*=8	4.22 (1.30) *n*=9	
Selective attention (visual search) [6]	31.17 (16.01) *n*=6	37.50 (13.84) *n*=8	

n indicate the number of patient who performed each task.

[1]Measso et al., 1993; [2]Frontal Assessment Battery (Apollonio et al., 2005); [3]Giovagnoli et al., 1996; [4,5,6]SpinnlerandTognoni, 1987.

CIB vs noCIB: # p<0.05

CIB vs controls: * p<0.05; **p<0.005

No-CIB vs controls:^ p<0.05

FIGURE CAPTIONS

Figure 1: Experimental conditions (top panel) and mean deviation of the line drawing (bottom panel) in Experiment 1. The bars represent standard errors.
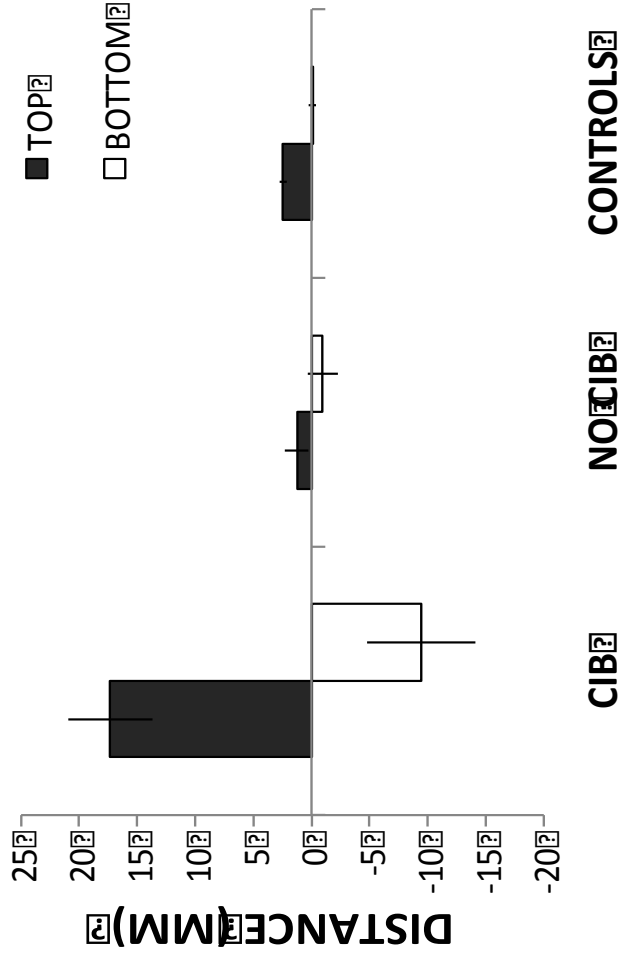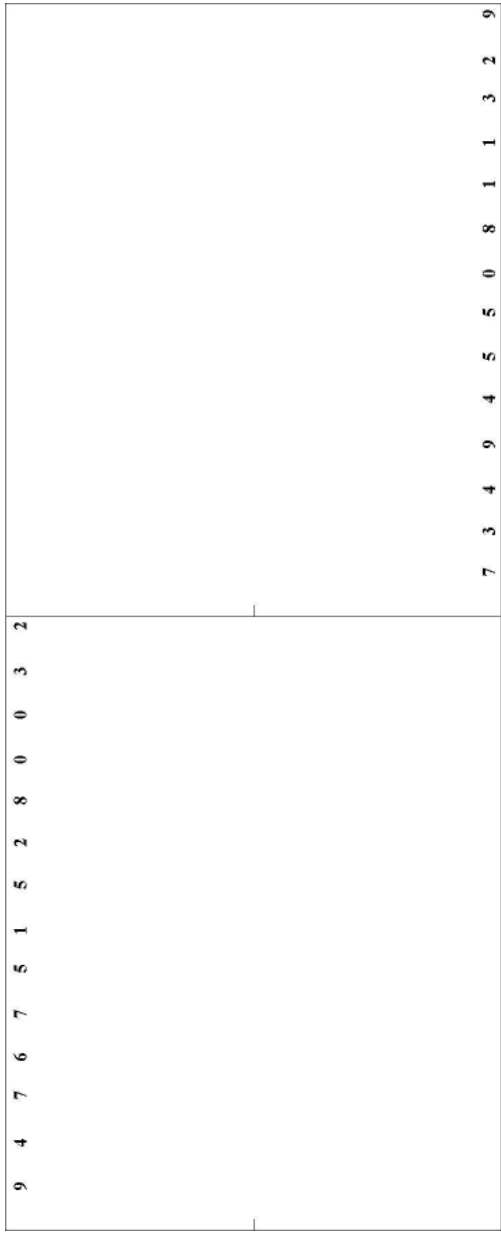
Figure 2: Experimental conditions (top panel) and mean deviation of the line drawing (bottom panel) in Experiment 2. The bars represent standard errors.

Figure 3: Experimental conditions (top panel) and mean deviation of the line drawing (bottom panel) in Experiment 3. The bars represent standard errors.

Figure 4: Experimental conditions (left panel) and mean deviation of the line drawing (right panel) in Experiment 4. The bars represent standard errors.

Figure 5: Experimental conditions (left panel) and mean deviation of the line drawing (right panel) in Experiment 5. The bars represent standard errors.
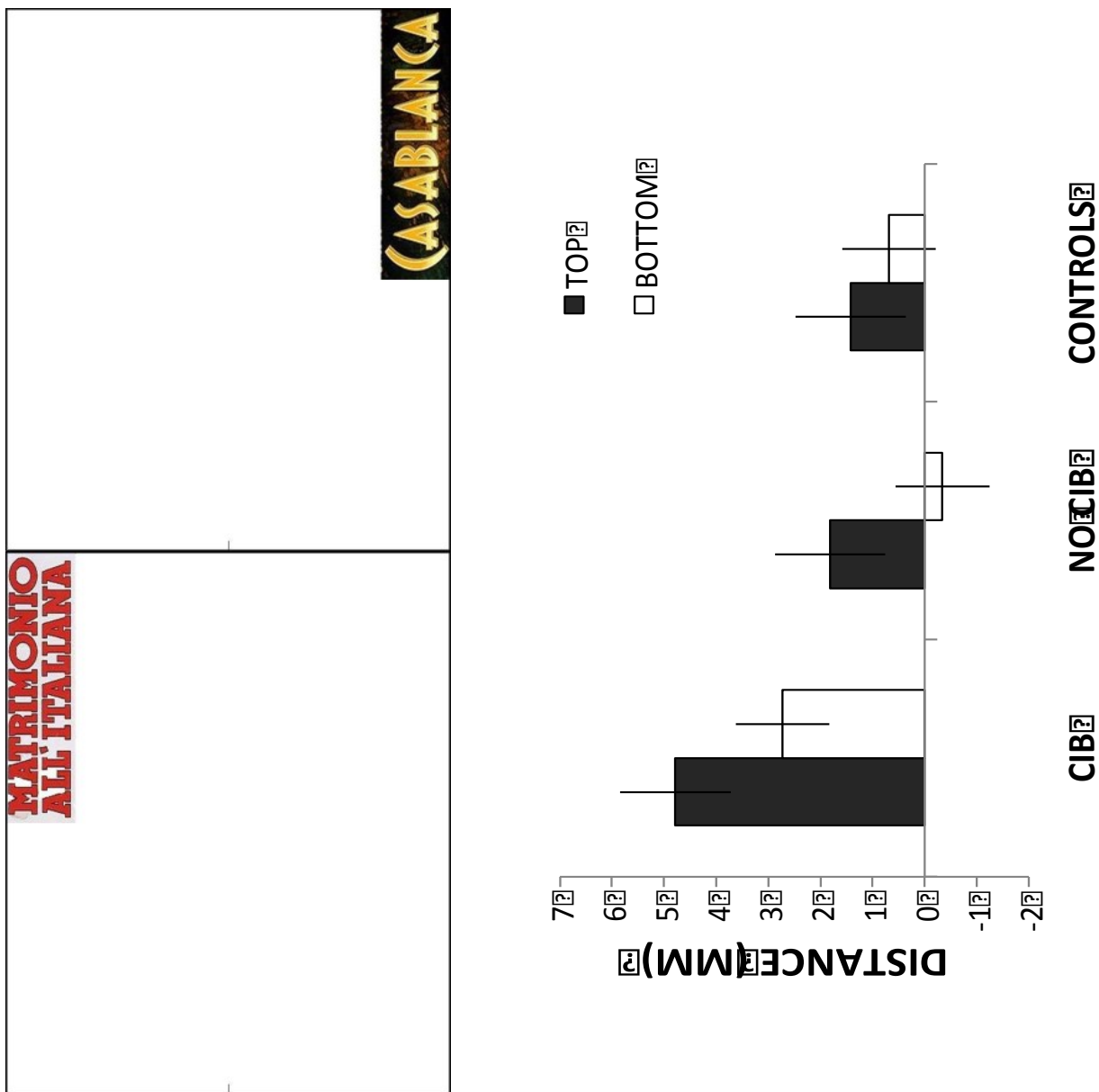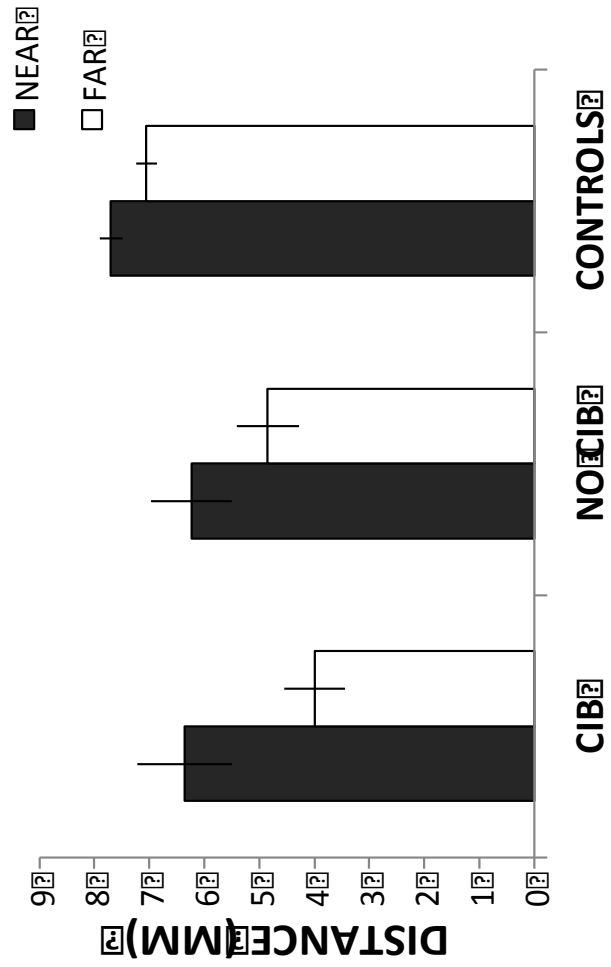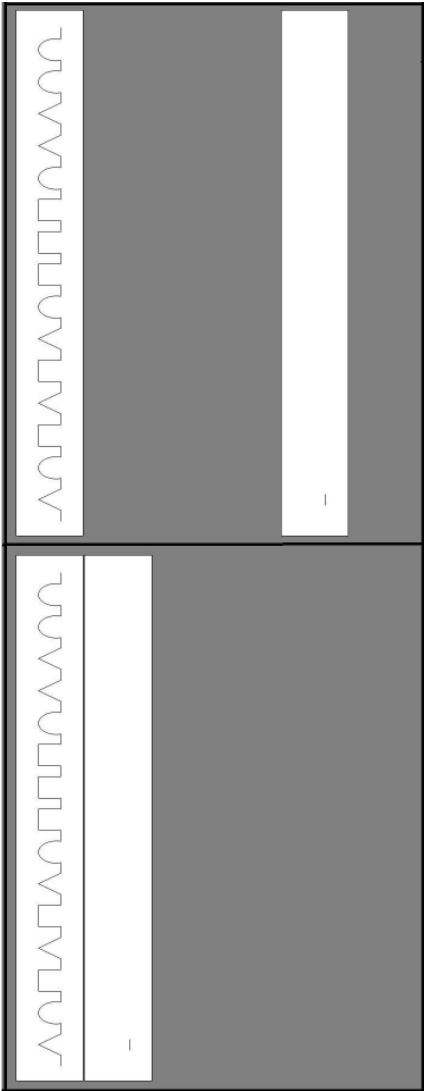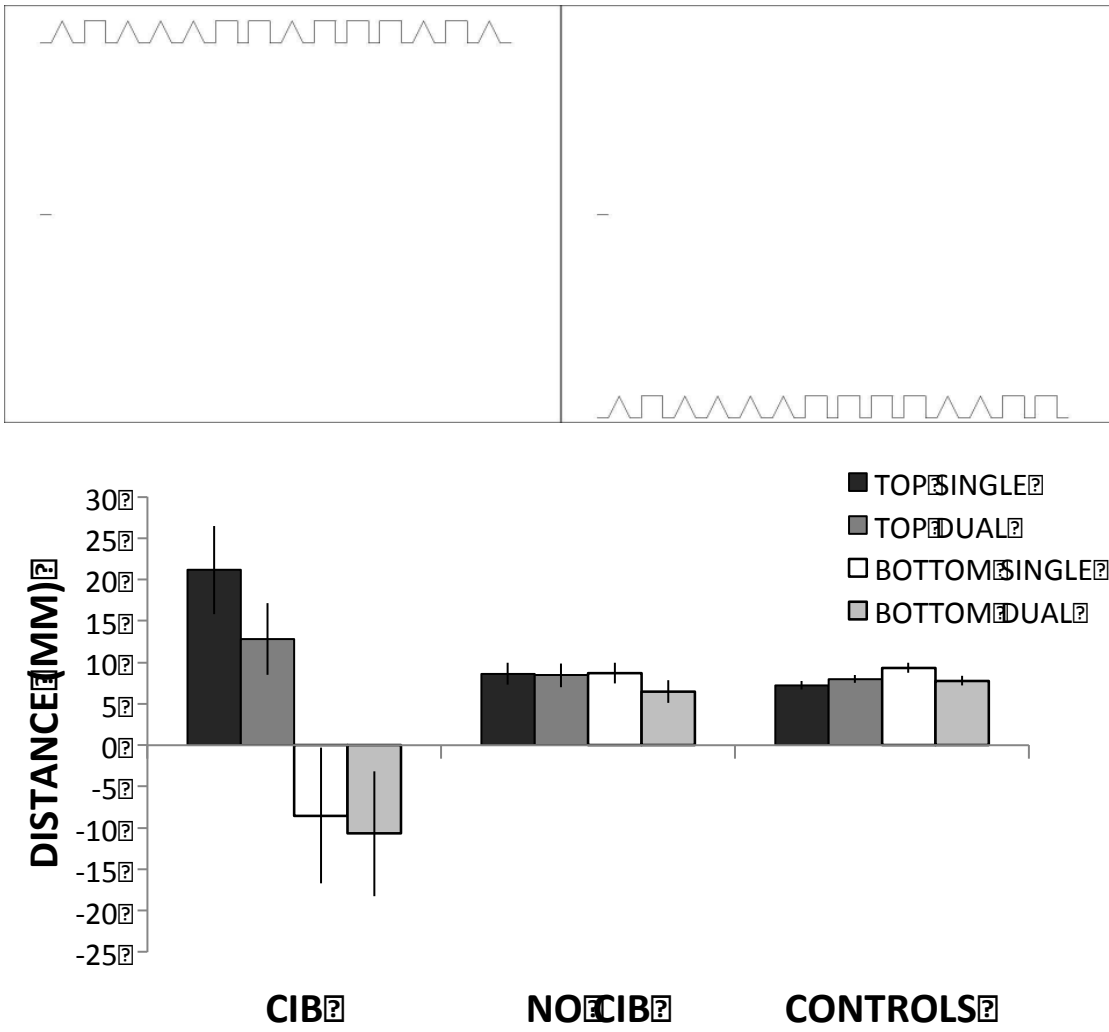
Fig 1

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