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A critical review of closing-in

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TITLE: A CRITICAL REVIEW OF CLOSING-IN

Abstract

When performing complex actions, like graphic copying or imitation of gestures, some patients may perform these actions very close to, or directly on the top of the model. This peculiar behaviour, known as Closing-in, is the focus of the present literature review, which will provide a critical picture of the research in this field, highlighting the difficulties in defining and assessing Closing-in and the contrasting results about the nature and the characteristics of this phenomenon. Most importantly, we will discuss the two hypotheses proposed to explain Closing-in, namely the compensation and the attraction account, in light of most recent works. This critical review will provide substantial evidence that Closing-in represent a primitive default tendency in which movements are attracted towards the focus of attention. On the other hand, the possibility that this interpretation might not be fully exhaustive and that different components of Closing-in might exist will also be discussed.

Closing-in: the Definition

Constructional Apraxia (CA) encompasses impairments of drawing, copying and assembling three-dimensional objects (Kleist, 1934). Some errors observed in CA tasks possess such defined characteristics to warrant clinical definition and experimental investigation in their own right (e.g., neglect errors, perseverations, spatial transpositions - Farah, 2003; Smith and Gilchrist, 2005). One such class of errors, observed in copying tasks, is characterised by copying abnormally close to, or directly on top of the model. This phenomenon was noted in passim by several neurologists in the early twentieth century (e.g., Goldenstein, 1948; Lhermitte, de Massary and Kyriaco, 1928; Lhermitte and Mouzon, 1941), but was first made the focus of research interest by Mayer-Gross (1935), who coined the term Closing-in (CI) to describe the symptom. He reported on the case of a patient affected by carbon monoxide poisoning and on five patients with probable dementia. These patients could copy simple figures by drawing or arranging mosaic tiles or blocks, but when the complexity of the model increased they would copy very close to, or on top of the model. A similar tendency emerged in imitation of hand postures, during which the patients would sometimes place a hand over that of the examiner. Figure 1 shows examples from the performance of one of Mayer-Gross' patients, who had been a professional artist. His drawings from memory are recognisable, though impoverished with respect to his premorbid abilities, and characterized by misplacement of elements. In copying figures made up of dots, he drew directly over the model; in writing, he superimposed new letters upon already-written ones, and in arithmetic, he wrote the resultant numbers over the digits to be added up. .

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

Subsequent authors interpreted Mayer-Gross' CI in broader or in more narrow terms, creating some confusion in the literature. At one extreme, Muncie (1938) extended the concept to encompass behaviours that could be considered 'model-directed' only in a very abstract sense. Thus, he classed as CI performances on top of the model in graphic copying and building tasks, but also included in its definition symptoms as varied as repetitive speech, echolalia, or echopraxia. He even labelled as CI the performance of a young sailor with schizophrenia who literally enacted some metaphorical advice ("Never let us cast a shadow by turning our back on the Sun"). At the other end, Critchley (1953) proposed that the term should be applied exclusively to errors of proximity to the model on graphic and

3D copying tasks, and that CI should be considered as a form of CA, indicative of parietal lobe dysfunction. His recommendation may have been over-prescriptive, precluding the reporting of manifestations of CI in tasks such as gesture imitation, free-drawing or writing; indeed, as we shall later argue, CI may reflect a rather general behavioural tendency. Nonetheless, Critchley's approach was undoubtedly useful in focusing attention upon concrete constructional behaviours.

Measurement of CI

In accordance with Critchley's (1953) definition of CI as a manifestation of CA, most copying tests pay no special regard to errors of proximity to the model, but weigh them into the total score alongside other copying errors (e.g., Cosentino et al., 2004; Rouleau et al., 1996). Even when test instructions specifically highlight CI, the score may not distinguish it from other constructional impairments. For instance, one copying test used in clinical setting which requires the patient to copy geometrical shapes of increasing complexity, yields a score from zero to two for each item, whereby zero is awarded if the copy is a mere scribble *or* is placed close to or on top of the model (Arrigoni and De Renzi, 1964; Spinnler and Tognoni, 1987). This kind of approach, though clinically convenient, precludes the assessment of the relationship between CI and other aspects of constructional performance. Thus, although copying tasks are some of the most common assessments in neuropsychology, the literature on CI is relatively sparse and scattered, being restricted to studies that have singled out this symptom for detailed analyses.

The study of CI presents challenges similar to those posed by other constructional errors, since the behaviour of interest needs to be abstracted from data (usually drawings) that are inherently qualitative. A tension arises between quantifying the severity of the error and preserving its particular character, and a gamut of approaches can be gleaned from the literature. At the most descriptive end, Gainotti (1972; see also Gainotti and Kluzer Usuelli, 1972) proposed four different manifestations of CI in graphic copying: scrawling inside the model; overlapping or bounding of the model; tracing lines from the model to the surrounding space; placing the copy near or adherent to the model. These categories are not mutually exclusive, and a single copy might earn multiple labels. However, specific scoring procedures were not defined, so that the classification depended heavily on the examiner's judgement; moreover, the nominal data produced by such typologies do not lend themselves readily to numerical analyses. Studies that have coded CI simply as present or absent may vary in the minimum proximity to

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the model at which the label is applied; and this critical criterion has rarely been made explicit (e.g., Grossi et al., 1978; Kuroiwa et al., 1967; Muncie, 1938).

More recently, investigators have opted for a more quantitative scoring procedure, such as grading CI manifestations on an ordinal scale of severity. For instance, Ober et al., (1991) used a scale for graphic copying with a score ranging from five (no CI) to one (copy on top of the model), though they did not provide clear criteria for each of these five levels. For gesture imitation, Kwon et al. (2002) graded CI on a scale from zero to three (0: no CI; 1: approaching examiner's hand; 2: touching examiner's hand; 3: grasping examiner's hand) (see also McIntosh et al., 2008). Moreover, if spatial proximity alone is taken as indicator of CI, then the symptom is amenable to finer-grained quantification, on continuous scales. Following Kwak et al., (2002), Lee et al. (2004) used variations of Luria's figure (Luria, 1966; McIntosh et al., 2008) (see Figure 2), a laterally extensive complex geometrical shape presented at the top of a sheet of paper for copying. This method is valuable for eliciting and quantifying CI, especially when the starting point for copying is fixed, because progressive deviation towards the model is reflected in the copy, which tends to slope towards the model from left to right. Lee et al. (2004; see also Chin et al., 2005) used this slope to quantify CI in patients with Alzheimer's Disease (AD), defining pathological cut-offs from the performance of healthy controls. To similar ends, the Luria figure has been used in several studies of CI (Ambron et al., 2010; Chin et al., 2005; De Lucia et al., 2014; Kwak, 2004; Kwak et al, 2002; Kwon et al., 2015; Lee et al., 2004; McIntosh et al. 2008; Sagliano et al., 2013). However, McIntosh et al. (2008) showed that a simple measure of average distance from model to copy might be a more sensitive and robust index of CI than the slope of the copy, as the assumption of linear migration towards the model does not always hold.

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

In this vein, Kwon et al., (2015) measured CI as the ratio between the initial and the final distances between the copy and model expressed in percentages. Other authors introduced what they called the 'tweaking index', a score computed by subtracting the minimum and the final distance between model and copy (De Lucia et al., 2014; De Lucia et al., 2015; De Lucia et al., 2016; Sagliano et al., 2013). This has the merit of providing additional information regarding the patients' self-corrections during copying and qualitative information regarding the patients' strategy to solve the task. Another approach,

which has been favoured in recent studies, consists in measuring the shortest distance between model and copy (Ambron et al., 2009a; De Lucia et al., 2014). This method might be more suitable when the graphic copying tasks comprise more structured geometrical shapes, like a square or a cube, in which CI might emerge more directly rather than developed in the course of the graphic copying as in the case of Luria's figure. Furthermore, the former copying task raises the important issue of varying the position of the model to elicit CI. This manipulation is crucial in particular for the laterally extended Luria's figure to distinguish model-directed deviations from other (e.g., upward) directional drawing biases (Ambron et al, 2009a; McIntosh et al, 2008; Sagliano et al., 2012).

Quantification has facilitated experimental investigations of factors influencing the severity of CI (see Sections 3 and 4). Nonetheless, an over-emphasis on quantification may have its own pitfalls. Scoring procedures that index proximity to the model embody the assumption that the range of CI manifestations lie on a continuum of severity, so that subtle veering is just a milder form of the same disorder that causes other patients to draw over the model. However, the largest available survey (Ambron et al., 2009a) of CI in AD (N = 797) has provided grounds to question this assumption, suggesting that Near- and Overlap-type CI may entail distinct neuropsychological counterparts (see Section 3).

A different approach consisted on the measurement of the distance between the model and the copy to cluster CI into two main classes: Near and Overlap (or Adherent) CI (De Lucia et al., 2013; De Lucia et al., 2014; De Lucia et al., 2016; Grossi et al., 2014; Grossi et al., 2015; McIntosh et al., 2008; Ambron et al., 2009a; Ambron et al., 2009b). Accordingly, Near CI identifies any graphic copy at 10 mm distance or less from the model and Overlap (or Adherent) CI classifies reproductions joined to the model (no distance between model and copy). Although arbitrary, this classification provides an objective and replicable criterion for the assessment of CI and eases the comparison across studies.

In addition, Ambron et al. (2009a; 2009b) proposed the assessment of CI independently from CA in order to investigate possible dissociation between these symptoms. Thanks to this method, they were able to classify CI within a more general disturbance of action and to demonstrate that CI can be associated with good constructional skills in some patients with Mild Cognitive Impairment (MCI)(n=13/33 MCI patients with CI (Ambron, McIntosh, Finotto, Clerici, Mariani, & Della Sala 2012a). To investigate whether similar dissociations could be observed in patients with AD, we have analysed further the dataset of patients described in Ambron et al.'s (2009a). In 312 cases (39%) CI was

found in association with CA, but in 31 cases (4%) it was coupled with good copying accuracy. The reverse dissociation could also be observed, as 370 (46%) AD patients showing no CI performed rather poorly on the CA task. Finally, 84 patients (11%) were able to accurately perform the copying task and showed no CI. A similar association between the presence of CI and relatively spared constructional skills has been reported by Conson et al. (2009) in a single case study. However, a possible criticism to this criterion is that the identification of only two main CI types may flatten further difference across CI clinical manifestations. For instance, following this classification, graphic copying simply touching the model on one edge would fall into the same category of drawings wholly overlapping onto the model. Although, both phenomena represent an invasion of the copy into the model space, it is debatable whether or not they reflect cumulative classes of errors rather than independent behaviours.

Anatomo-clinical Correlates of CI

CI has been reported in single cases with various diseases, including dementia, stroke, carbon monoxide poisoning, corticobasal degeneration, encephalitis, and epilepsy (see Table 1). From these sporadic and heterogeneous reports, it is hard to identify a clear pattern of brain areas associated with CI. The classical association between CI and CA, indicative of posterior brain damage, has been confirmed in few single case reports of patients with CI who suffered from focal lesions in the parietal lobe (Critchley, 1953; Kwon et al., 2002; Suzuki et al., 2003). However, CI has also been noted in patients suffering from frontal dysfunctions (Conson et al., 2009; Septie et al., 1992), weakening the idea of an exclusive association between CI and posterior brain lesion. Moreover, a SPECT study (Midorikawa et al., 1996) demonstrated reduced activity in both the parieto-occipital and the frontal areas in patients with AD, who showed both CI and CA in constructional tasks.

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

Similar observations arise when looking at groups' studies (Table 2). As for single cases, CI is reported in a variety of brain diseases, mostly in patients with focal brain damaged or dementia. Studies with focal brain lesion patients are dated and do not go further than assessing CI frequencies in relation to the side of the lesion. A more recent study (De Lucia et al., 2016) found CI to be more common in right than left brain-damaged patients, and in patients with frontal than subcortical lesions (see Table 2),

confirming the preferential association between CI and the right hemisphere observed in single cases (Grossi et al., 1996; Pavan, 1966). However, other authors have reported CI to be more common in left than right brain damaged patients (Piercy et al. 1960). These contrasting results might reflect the different distribution of Near and Overlap CI in the various studies. Studies reporting the frequency of CI being greater in right-brain damaged patients referred mainly to Near CI (De Lucia et al., 2016) or a partial Overlap CI (i.e. the edge of the copy touch the model)(Grossi et al., 1996; Pavan, 1966). Instead, studies investigating the tendency superimpose or considering only Overlap CI, reported the behaviour as either more common in left-brain damaged patients (Piercy et al. 1960) or equally frequent in left and right-brain damaged patients (Gainotti & Tiacci, 1970). However, this observation remain speculative as the variety of the tasks used and of the definition of CI across studies make difficult to draw substantial conclusions regarding a definite lateralization of CI with respect to Near and Overlap types.

With respect to dementia, one study found that the frequency of CI was greater in patients with dementia than in brain-damaged patients (Gainotti, 1972). This association between CI and dementia has been confirmed and specified in a number of large survey studies (Ambron et al., 2009a; 2009b; De Lucia et al., 2013; 2014; Grossi et al., 2014; 2015). Among the different forms of dementia, CI has been classically conceived as a common feature of AD (Ober et al., 1991; Rouleau et al., 1996; Spinnler and Della Sala, 1988) with estimated frequencies ranging from 38 to 77% (see Table 1). As previously stressed, the variety of definitions of CI, the multifarious tasks used and the different assessing criteria complicate the direct comparisons across studies in AD. In AD, the frequency of the phenomenon is highly dependent on the complexity of the copying task and on the severity of dementia (Ambron et al., 2009a; 2009b). Ambron et al. (2009a; 2009b) have shown that the frequency of CI (and the relative occurrence of Near and Overlap types) increases in severe dementia and when the copy task is more complex, these factors may additionally contribute to the differences in CI frequencies estimated across studies.

----- Insert Table 2 about here -----

The association of CI with AD, compared for instance to Vascular dementia (VaD) (Gainotti et al., 1992; De Lucia et al., 2014), has led some authors to propose it as a specific marker of AD (Gainotti et al., 1998). However, recent work questions this proposal and rather reinforces the association between CI and relatively advanced dementia stages (Kwak, 2004). The discrepancy in CI frequencies across

different types of dementia evaporates when patients' groups are matched by severity, both when comparing AD with VaD (Chin et al., 2005) and AD with Fronto-temporal dementia (FTD) (Ambron et al., 2009b). In particular, Ambron et al. (2009b) showed that CI (Near and Overlap types combined) is equally common in AD and FTD at each level of dementia severity (mild, moderate and severe), but it presents with different features. CI in AD is modulated by the complexity of the copying task, as it is CA, while CI in FTD appears to be rather independent from the visuo-spatial load of the task. Although these results suggest slightly different cognitive substrates of CI in these two groups, they were limited to the observation of superficial characteristics of CI as the neuropsychological underpinnings of the phenomenon were not directly investigated. Similarly, De Lucia et al. (2014) have shown that the magnitude of CI in AD increases by enhancing the general cognitive demand in copying tasks, whereas more stable performance across tasks is observed in VaD. Taken together, these observations suggest that CI manifestations may vary according to specific form of dementia.

Despite the open debate on whether or not the phenomenon is linked to a specific form of dementia, the widespread presence of CI in a variety of neurodegenerative processes suggests that rather than being a unique symptom released by damage to a specific brain area CI may depend upon different lesion locations. A recent study investigated the neuroanatomical correlates of CI in a sample of 38 AD and 21 matched healthy controls using voxel-based morphometry multiple regression analysis (Kwon et al., 2015). This analysis was conducted with CI score, defined as the ratio between initial and final distance (see previous section), as main variable and demographics, cognitive impairment (measured by means of the Mini Mental State Examination) and the total intracranial volume as covariates. The authors found that in both groups CI was associated with a reduction of grey matter volume in the orbito-frontal cortex bilaterally. These results combined with the observation that CI is as common in AD as it is in FTD (Ambron et al. 2009b) support the hypothesis of a frontal nature of CI (De Lucia et al., 2014; De Lucia et al., 2016; Kwon et a., 2009; McIntosh et al., 2009). On the other hand, although sporadic, observations of CI following parietal lesion have also been reported (Critchley, 1953; Kwon et al., 2002; Mayer Gross, 1935; Suzuki et al., 2003).

Cognitive Correlates of CI

CI has been noted in association with several neuropsychological deficits and systematic patters of associations do not seem to emerge (see Table 1). However, some observations can be drawn from extant

literature. As shown in Table 1, CI (i) has been described in one or more domains (graphic copying, imitation of gestures and writing); (ii) is often associated with CA (although this association might be overestimated as related to the methodological issue described in the previous section); (iii) is observed within a frame of memory and visuo-spatial impairment but has been reported also in cases whereby these abilities were spared; (iv) has been reported in association with neuropsychological symptoms like utilization behaviour or grasping reflex, known to reflect frontal dysfunction. Furthermore, some patients are unaware of CI (Muncie, 1938), whereas others show a sense of frustration in noting it (Mayer Gross, 1935; De Ajuriaguerra et al., 1949).

Some recent studies have been devoted to explore the cognitive underpinnings of CI, both Near and Overlap types, in different patients groups (Ambron et al., 2009a; Serra et al., 2010; De Lucia et al., 2013; De Lucia et al., 2015; Grossi et al., 2014; Grossi et al., 2015). This line of research developed in the light of two competing hypotheses of CI, namely the Compensation and the Attraction account of CI (Lee et al., 2004) which identify respectively two distinguished clusters of cognitive functions related to CI: visuo-spatial/constructional abilities and/or working memory on one-side and attention/executive functions on the other. A study assessing the cognitive predictors of CI analysed retrospectively the records of 797 patients with AD, comprising of a brief but comprehensive battery for the assessment of several cognitive functions (Milan Overall Dementia Assessment; Brazzelli et al., 1994). For 132 of these patients longitudinal data were also available. The results of both the large AD cohort and the longitudinal data pointed to the impairment in an attentional task (a visual search test; Della Sala et al., 1992) as the main predictor of CI. However, the amount of attentional impairment varied depending on the type of CI; while attentional deficits alone predicted the appearance of Near-type CI with respect to normal performance, the distinction between Overlap CI and Near CI (or normal performance) was best predicted by both attention and visuo-constructional skills (Figure Copying). Furthermore, CI deterioration in the longitudinal sample was also predicted by changes in the attentional test. Taken together, this evidence supports the link between CI and impairment in attention, but also suggests that visuo-contructional problems play a role in the expression of Overlap CI. Therefore, these two forms of CI may not simply lie on a continuum of severity but could reflect a different involvement of attention and visuo-spatial deficits (Ambron et al., 2009a).

These results were partially replicated in a smaller cohort of patients with AD (De Lucia et al., 2013), who underwent a more detailed neuropsychological assessment, comprising of specific executive

functions, visuo-spatial and visuo-contructional tasks. In line with Ambron et al. (2009a), the authors found that impairment in both executive and visuo-constructional tasks predicted the presence of CI (both Overlap ad Near CI combined in an unique score), whereas visuo-spatial and memory functions did not contribute to the manifestation of the phenomenon. When looking at the predictors of Overlap (Adherent type in their nomenclature) CI with respect to Near CI executive functions score, and specifically the Stroop Task (Caffarra et al., 2002), was the only significant predictor distinguishing these two forms of CI. This evidence reinforced the hypothesis that CI is related to response inhibition deficits (Ambron et al., 2009a; McIntosh et al., 2008; De Lucia et al., 2013), released by frontal lobe dysfunctions (Kwon et al., 2002; Lepore et al. 2005). Accordingly, Ambron et al., (2012a) reported that in patients with MCI CI was more common in multi-domain non-amnestic MCI (41%) than in multi-domain amnestic MCI (19%), undermining the possible role of memory deficits in the release of CI. Performance on an executive function test battery, namely the Frontal Assessment Battery (FAB), was the only test discriminating between patients with and without CI.

Lately, further direct and indirect evidence supporting the association between CI and executive deficits has accrued. First, the presence and severity of apathy, a symptom associated with frontal lobe alterations in AD (Craig et al., 1996), has been reported as the best predictor of the severity of CI (i.e., the number of occurrence of CI across tasks) in patients with AD (Grossi et al., 2014). Second, the phenomenon has been observed in patients with Parkinson disease (De Lucia et al., 2015; Poletti et al., 2012), in whom executive functions represent the core cognitive deficits (Ravizza et al., 2012). In this sample, basic motor impairments did not predict the appearance of CI, suggesting that it cannot be conceived as a simple motor deficit. Third, across studies with patients affected by different brain degenerative diseases, executive and/or attentional deficits emerged consistently as the best predictor of CI or the main factor distinguishing between patients with and without CI (Ambron et al., 2009a; De Lucia et al., 2014; De Lucia et al., 2015; Grossi et al., 2014; Grossi et al., 2015). Finally, CI was found to be associated with other frontal symptoms, such as environmental dependency symptoms (utilization behaviour; imitation behaviour), in patients with behavioural variant fronto-temporal dementia (bv-FTD) (Grossi et al., 2015). In this study, Grossi et al. (2015) showed that Overlap CI, but not Near CI, was always associated with environmental dependency symptoms. When looking at the possible predictors of CI or environmental dependency symptoms independently, executive impairment (FAB and verbal fluency) resulted the unique predictor of both symptoms reinforcing the hypothesis of a common

cognitive origin for these symptoms. Hoverer, applying regression analysis the authors showed that CI was not predicted by environmental dependency, suggesting that these disturbances are independent, although possibly part of the same constellation of symptoms.

Not everybody agrees. For instance, Serra et al. (2010) showed that a poor performance in visuo-spatial tasks (Corsi Blocks), rather than in executive tasks (verbal fluency test) was the best determinant in distinguishing patients with Overlap CI from those without CI. Furthermore, the frequency of frontal lobe associated-symptoms, as primitive reflexes (palmo-mental, glabella and grasping reflexes), did not vary between patients with and without CI (Serra et al., 2010), weakening the hypothesis of a unique and causal relationship between anterior lesions and CI.

To summarize, this overview points towards executive dysfunctions as the likely cognitive underpinning of CI, but the contribution of visuo-spatial deficits (Ambron et al., 2009, Serra et al., 2010) cannot be excluded. Also, the cognitive correlates of CI point towards a frontal nature of this symptom. However, as discussed in section 3, the possible role played by posterior brain damage in CI cannot be disregarded.

CI across Life Span

CI is not confined to brain damages or lesions, but it has been noted across lifespan in neurotypically developing children (Prudhommeau, 1947; Wallon and Lurçat, 1957), in healthy aging (Kwak, 2004), and also in younger adults under specific task conditions (Sagliano et al., 2012). CI is common in 2-3 years old children performing graphic copying (Ambron et al., 2009c; 2010; Gainotti, 1972; Mendilaharsu et al., 1970), but its frequency decreases progressively and the phenomenon disappears around the age of 5-6. This pattern mirrors the CI distribution observed in AD consisting in the progressive increase of CI as dementia becomes more severe (Ambron et al., 2009a).

CI in childhood features similarities with CI in dementia (e.g., Ambron et al., 2009c, 2009d; Gainotti, 1972; Mendilaharsu et al., 1970). A close relationship between CI and accuracy of the graphic copying has been noted in both development and dementia. In children, constructional skills improve with development (Ambron et al., 2009c), whereas dementia progression hampers the accuracy of the reproduction and CI becomes more frequent (Ambron et al., 2009b). The frequency of CI and of poor graphic accuracy rises with increasing the complexity of the shapes to be copied both in children (Ambron et al., 2009c) and in patients with AD (Ambron et al., 2009a). Recent work which examined

the relationship between CI and performance in visuo-spatial, working memory, and attentional tasks in children (Ambron et el., 2009d), provided converging evidence for a primary role of attention deficits in the appearance of CI in children (Ambron et al., 2009a; De Lucia et al., 2013; Grossi et al., 2014). Furthermore, performance in an attention-switching task was the best predictor of CI in children (Ambron et al., 2010), suggesting a possible link between the phenomenon and poor monitoring, a key ability required in copying tasks. Interestingly, this task did not require spatial attentional switching between locations, but rather switching between two different tasks. The structure of this task mimicked somehow the demand of copying task where people are required (i) to perceive and attend the model without acting towards it and (ii) to attend and to act upon the copy. This evidence is noteworthy in the debate regarding the possible interpretations of CI discussed in the next section.

A mild form of CI has also been noted in normal aging. Kwak (2004) found Near CI in two out of 22 older volunteers (mean age=67.30; SD = 8.46), whereas the phenomenon was not observed in young adults. Similar results were obtained by Lee et al. (2004), who found that older individuals (mean age = 68.6; SD = 8.1) showed an upward slope in drawing Luria's figure, suggesting a mild tendency to draw towards the model at the top edge of the page. As attention and executive functions are commonly affected by the aging process (Mayr et al., 2001; Turner and Spreng, 2012), it is tempting to speculate of a possible direct connection between these functions and CI as observed in dementia. However, an alternative interpretation is that the overall age-related cognitive decline increases the demand of the copying task, making the phenomenon more likely to emerge. This interpretation would provide an account for less severe form of CI, whereas Overlap CI has never been observed in healthy adults and remains confined to people affected by brain pathologies.

Sagliano et al. (2012) investigated whether young adults may also show Near CI by increasing the general demand of the copying task. Participants were asked to copy laterally extended Luria's figure as a single task or in a dual task conditions, which required counting forwards or backward. Young adults were able to inhibit the tendency to draw towards the model in the simple coping task, whereas a bias towards the model was observed in the dual task condition. The authors interpreted these results as evidence that CI can be elicited in normal adults by increasing the overall demand of the task and loading upon attentional resources. In line with previous interpretations (Ambron et al., 2010; McIntosh et al., 2008), the authors proposed that CI might arise in healthy adults performing a dual task, as this condition requires dividing and switching attention between the primary copying and the secondary tasks. Taken

together these findings suggest that CI, at least in its milder form, is not only a sign of a pathological process, but it may also be a default phenomenon observed across lifespan.

Accounts of CI

Early theories of CI assumed it to be a manifestation of CA and extended the interpretations of CA to account also for CI (Critchley, 1953). Mayer Gross (1935) interpreted CA as a general disorder of the hand and fingers placement in the space, whereby CI reflected a specific alteration of the space extension. These deficits would be caused by the emergence of this "primary biological protective mechanism" of hands and fingers to move towards anything to fill the space. After Mayer Gross, other interpretations flourished in the earlier reports. CI was then interpreted as the reappearance of the primitive spatial representation between objects, based on proximity alone (Stengel and Vienna, 1944), as a symptom of the confusion between personal and extra-personal space (Critchley, 1953); and as the inability to act in an open space (De Renzi, 1959). These interpretations developed around two key factors: the alteration of visuo-spatial perception and emergence of a primitive behaviour. These two factors still distinguish the two main account of CI dominating the contemporary cognitive framework: the compensation and the attraction hypotheses.

First championed by Muncie (1938), who interpreted CI as a difficulty in symbolic abstraction from a concrete model, the compensation hypothesis posits that CI would reduce the effect of visuo-spatial and/or working memory deficits (Kwon et al., 2002; Lee at al., 2004). These deficits may occur at different levels, from the perception and analysis of the model, to the creation of a mental representation of the shape, to the ability to maintain this representation in memory (Grossi et al., 1996). To overcome these difficulties the patient would perform close to the model to reduce the visual distance between the model and the space of copying.

On the other hand, the attraction hypothesis envisages the possible primitive nature of CI (Vereecken, 1958; De Ajuriaguerra et al., 1960; Gainotti, 1972). Early interpretations proposed CI to be akin to a visual manifestation of grasping reflex, in which the hand is attracted towards any stimulus presented in the visual field (Vereecken, 1958) and used the association between CI and primitive behaviours like grasping or sucking reflexes, echolalia, and echopraxia as evidence of the reappearance of a primitive "sensory-motor" organization in severe dementia (De Ajuriaguerra et al., 1960; Gainotti, 1972). Based on the observation that CI is not confined to neuropathology, but it is also observed in early

childhood (Prudhommeau, 1947; Wallon and Lurçat, 1957), this account proposed that CI may represent a primitive general default behaviour, commonly observed during the first stage of human life, and then partially inhibited during development (Gainotti, 1972). CI would be like other primitive behavioural patterns, which reappear in neuropathology due to the disruption of higher executive mechanisms (De Ajuriaguerra et al, 1960; Gregory, 2001).

In line with this primitive behaviour hypothesis, other authors (e.g., Conson et al., 2009) revamped the competitive tropisms theory introduced by Denny-Brown (Denny-Brown, 1956; 1958; Denny-Brown and Chambers, 1958) as a possible interpretation of CI. This theory postulates that two types of motor responses to environmental stimuli occur in brain-damage patients (and monkeys with ablation of parietal or frontal lobes): avoiding and approaching responses. The first set would represent the negative tropism and would follow parietal lobe damage, whereas lesions involving the frontal lobes produced approach behaviours, such as instinctive grasping and palpations. Within this frame, CI is conceived as a manifestation of this last set of behaviours known as positive approach tropism. Although valid, as formulated, this hypothesis suggests a direct and causal relationship between CI and frontal lobe damage and does not readily accounts for CI in patients with damage elsewhere.

In addition to the positive tropism interpretation, the attraction account of CI has been recently specified in details. CI has been described as a primitive coupling between attention and action, in which the active hand is drawn towards the focus of attention (Kwon et al., 2002; Lee at al., 2004; McIntosh et al., 2008). The assessment of eye movements during graphic copying of patients with AD and CI (Midorikawa et al., 1996) partially supports this primitive coupling interpretation. Midorikawa et al. (1996) showed that eye movements of patients with Overlap CI were locked on fixation within the model area, while small saccades were observed in normal participants performing the same task. However, the same was not true for milder forms of CI, in which this locking type of fixation was combined with anomalous eye movement around the model area, supporting the idea that Overlap CI might represent a deficit in decoupling vision and action, but implying that slightly different mechanisms might be responsible for milder forms of CI. As stated, the attraction hypothesis defines the nature of CI, as a default tendency to perform actions towards the focus of attention. Additional specifications of the attraction hypothesis have postulated that CI may depend upon a reduction of attentional and/or executive resources (Conson et al., 2009; Kwon et al., 2002, Lee at al., 2004).

As described in the previous paragraphs, both the compensation and the attraction accounts have received support from large survey studies, which have identified as possible cognitive correlates of CI visuo-spatial and/or visuo-constructional deficits (Serra et al., 2010; De Lucia et al., 2015), or attention and/or executive deficits (Ambron et al., 2009a; De Lucia et al., 2015; 2014; Grossi et al., 2013; 2014). Although across studies, attention and executive functions recur often as cognitive correlates of CI and have also been identified as core CI-related-abilities in children (Ambron et al., 2010), correlational studies do not provide definitive results able to distinguish between the two competing interpretations. Experimental studies designed ad hoc to test between CI accounts have provided more direct hints regarding the nature of the phenomenon and will be described in details in the next section.

Experimental Evidence

A few studies have attempted to test experimentally between the two main account of CI in both graphic copying and imitation of gestures. However, most of the studies manipulated two main factors: the complexity of the model to be copied (or the gesture to imitate) and/or of the task (De Lucia et al., 2014; Kwon et al., 2002), and the distance between the model and copying space (Lee et al., 2004). The rationale beyond these manipulations is to investigate whether CI is enhanced increasing the visuo-spatial and working memory demand of task, as the compensation hypothesis predicts the increase of CI in copying more complex shapes and with a bigger gap between copying and model space. The results across studies show that the distance between the model and the copy does not specifically affect CI (De Lucia et al., 2014; Lee et al., 2004; Kwon et al., 2002), whereas less consistent patterns are reported for the complexity of the model. The complexity of the model, in either graphic copying or gesture imitation, has been noted as a main factor increasing the frequency of CI (Ambron et al., 2010; Ambron et al., 2009a; McIntosh et al., 2008; Gainotti, 1972). It has also been reported as not enhancing the frequency or severity of CI (Conson et al., 2009; Kwon et al., 2002). However, a closer look at this set of results indicates that this inconsistency might depend on the specific cohort of patients under investigation. While the complexity effect has been noted in patients with AD, this factor does not characterize CI in corticobasal degeneration (Conson et al., 2009; Kwon et al., 2002) or patients with frontal lobe dysfunction (Ambron et al., 2009b). This observation is in line with the hypothesis of a different nature of CI in patients with FTD, whereby the phenomenon appears related to a decrease in inhibition and of executive resources associated to the reduced functionality of the prefrontal cortex. The nature of the

behaviour in AD may be slightly different as reflecting the additional involvement of visuo-spatial impairments (Ambron et al., 2009b). On the other hand, as in Section 3, it is also possible that CI, may rely on two independent components (visuospatial and executive), which might or not interact at certain levels. Both these interpretations are however speculative and these accounts needs to be properly investigated.

Taken together, the lack of significant effects of distance and/or complexity of the shape have been interpreted as contradicting the compensation hypothesis and as supportive evidence of the attraction hypothesis. The main argument is that being conceived as a primitive behaviour following the attraction account, CI would be released independently from the manipulation of these external factors like the distance or the complexity of the shape (Conson et al., 2009; Kwon et al., 2002). However, the attraction hypothesis proposes likewise that the release of CI is related to attention and/or executive deficits. By increasing either the complexity or the distance, the overall demand of the task will increase as so the loads on attention and monitoring abilities. Therefore, as the compensation hypothesis, the attraction account may equally predict the enhancement of CI in more complex tasks, making these manipulations, as defined, a weak test to disentangle between the two CI accounts.

Another manipulation used to test CI accounts lies in the visual presentation of the model during the execution of the copy. Conson et al. (2009) found that the performance of a patient with CI in graphic copying improved in term of accuracy by removing the model and asking the patients to draw on command. The outcome strengthened the idea that CI reflects a general movement bias towards the focus of visual attention and this misplacement of the graphic copying influences the accuracy, altering the spatial relationship between the different elements of the copy drawing.

A series of studies used dual task paradigms to explore CI (Ambron et al., 2009c; De Lucia et al., 2013; McIntosh et al., 2008). One line of research (De Lucia et al. 2014; De Lucia et al. 2016) used graphic copying of Luria's figure as primary task and a verbal working memory as the secondary task (i.e., counting forward). However, this manipulation suffers from the same criticism as the complexity of the copying task. Although loading on verbal rather than spatial working memory, this dual task manipulation increases the overall demand of the task fulfilling the prediction of both accounts. A different type of dual task paradigm has instead provided a more decisive experimental test of these hypotheses. First tested in a single case study of a patient with AD and both gestural and graphic CI (McIntosh et al., 2008), this line of research identifies in the 'modality specificity' the key factor able to

distinguish between the two hypotheses of CI. The compensation hypothesis posits CI as a strategy used to carry out the copying task despite the patient's visuo-spatial and/or working memory deficits and predicts the appearance of CI in situations in which the manual performance benefits directly from the information available at specific location, as in the case of copying whereby patients would perform the copy in close proximity to the model in order to complete the motor task.

On the contrary, the attraction account considers CI as general default behaviour, consisting in a magnetic attraction of the movements towards the focus of attention. Using this crucial distinction, McIntosh et al. (2008) devised dual tasks for graphic and gestural CI to test between the two compelling hypotheses. The primary task required the execution of a simple movement: drawing a straight line or perform the repetitive gesture palm down. The secondary task required reading aloud a series of letters, which were either printed on the top or bottom of the sheet of paper in graphic experiment, or presented in a series of cards showed by the examiner on the right or left side of the patient in the gestural CI. The results of this study showed that in both drawing and gestural domain, the patient's performance migrated towards the location of the letters, as posited by the attraction account of CI. These results suggested that CI is not specific to copying tasks, but rather a default bias toward the focus of attention. These results have been replicated in pre-school children (Ambron et al., 2009c). In the latter case the straight-line drawing task was combined with an animal-naming task and pre-school children showed equivalent behaviour to the patient with AD: the primary manual performance was executed toward the target-stimuli of the secondary task.

In line with the attraction hypothesis, these results strengthen the view of CI as a general default tendency of the motor system to respond and act towards the focus of attention. In this context, CI reminds of optic ataxia (OA) a symptom observed in association to posterior parietal lesions (Perenin & Vighetto, 1988) and consisting in misreaching of targets presented in peripheral vision. Interestingly, the movement trajectories of patients with OA tend to be shifted towards the focus of fixation (Ambron et al., 2015; Blangero et al., 2010), suggesting that OA could reflect a possible default attraction of the movements towards fixation (Milner et al., 2003). Although it is tempting to speculate a link between CI and OA, as suggested by one of the reviewers of this paper, to date there is no evidence supporting their relationship. The presence of OA was tested in a single case study (Mcintosh et al., 2008) but this patient who showed very severe CI did not show any sign of OA.

Although the release of CI may be primarily associated with attention and executive deficits, rather than being a more basic motor deficits (De Lucia et al., 2015), different mechanisms may be responsible of such coupling between attention and action. One hypothesis is that CI may be associated specifically to the difficulty in attending the model and in performing the action at a different spatial location from the focus of attention (Ambron et al., 2010; De Lucia et al., 2014). A difficulty in dividing and switching constantly between these two tasks may resolve in the tendency to couple attention and action, and to perform the movement towards the focus of attention. CI may also reflect a deficit in the inhibition of action automatically primed by attended stimuli (Ambron, Della Sala, & McIntosh, 2012b; De Lucia et al., 2013). This last account links CI to a phenomenon observed in healthy young adults known as the 'distractor effect' (Meegan and Tipper, 1998; Tipper et al., 1998; Welsh et al., 1999; Welsh and Elliott, 2005; Welsh, and Elliott, 2004). When performing reaching tasks, the presence of a non-target stimulus (distractor) influences the temporal and/or spatial parameters of the on-going action towards the target. In particular, the movement trajectory can be either attracted towards the distractor stimulus (Chieffi et al., 2001; Welsh and Elliott, 2004, 2005; Welsh et al., 1999) or veer away from its location (Howard and Tipper, 1997; Tipper et al., 1997) depending on the level of attentional capturing properties and relevance of the distractor stimulus. In particular, the population-coding model (Tipper et al., 1998; Tipper et al., 2000) posited that the presence of a distractor activates and elicits a response towards its location, which competes with the response towards the target. Depending on whether the response elicited by the distractor is enhanced or inhibited when the movement is initiated, the trajectory will veer away or towards the distractor location. Specifically, a bias away from the distractor location would be likely to occur when inhibitory resources can be activated and can counteract the response towards the distractor; whereas a tendency to veer towards the distractor may reflect a primitive response, occurring prior inhibitory mechanism come into play. This can occurs with salient and/or unexpected distractors, which attract attention exogenously, but even more when attention is voluntary directed towards the distractor (i.e., distractor is task relevant). On the other hand, the tendency to veer towards the distractor would be even more likely to emerge when the overall inhibitory abilities are altered for either the immaturity or damage to the attentional and/or and executive system.

It has been proposed that the distractor effect may reflect a primitive configuration of the motor system to respond to attentional capturing stimuli with CI representing its extreme and pathological manifestation (Chieffi et al., 2001). If these two phenomena are somehow related, people displaying CI

should be more prone to distractor interference in reaching than similar cohorts without CI. Ambron et al. (2012) tested this hypothesis in pre-school children using task-relevant and task-irrelevant distractors. Both tasks were presented on a touchscreen and participants were required to perform a reaching movement connecting the starting point with a target. At the same time as the target, a non-target stimulus (distractor) was presented on the right or left side of the target location. In the task-irrelevant distractor, participants were asked ignore the distractor while performing the reaching movement. In the task-relevant distractor, two targets (blue and red stimuli presented on the right and left side of the screen) were displayed and participants were asked to look at the colour of the distractor (either blue or red) in order to select the correct target to reach during each trial. Therefore, while the irrelevant distractor task loaded on automatic attentional capturing mechanism (exogenous attention), the task-relevant distractor required voluntary direction of attention towards the distractor location (endogenous attention). In this sense, this last set of attentional mechanisms are more difficult to inhibit and more likely to enhance a distractor effect. In line with this interpretation, the authors found that children with and without CI showed a strong bias to veer towards task-relevant distractor, which was of a similar magnitude in these two groups (Ambron et al., 2012b). With task irrelevant distractor, the tendency to veer towards the distractor was reduced in children without CI, while it remains consistent in children with CI, who showed a larger bias towards the distractor than children without CI.

Taken together, these data support the view that CI reflects a default tendency to respond towards the focus of attention. Both endogenous and exogenous attentional capturing mechanisms might be able to enhance this effect, but while endogenous mechanism guarantee attention to be focus on the distractor making the elicitation of CI straightforward, the ability of exogenous attentional capturing mechanism to enhance CI will depend strongly on the characteristics of the non-target stimulus. This interpretation is also in line with the results obtained with different dual task paradigms as discussed in the previous sections, showing a worsening of CI during dual task conditions in which attention is allocated towards the execution of another task (De Lucia et al., 2014; De Lucia et al., 2016; McIntosh et al., 2008). However, this account might not be an exhaustive explanation of CI, but it might be restricted to specific manifestations of this symptom released by certain neuroanatomical changes. This latter interpretation appears to be plausible, taking into account the discussed difference in CI features across neurodegenerative disorders. Hence, a consistent pattern of association between CI and executive and/or attentional deficits emerges, this association might not be univocal and other components of CI

might also exist. Similarly, correlational and a neuroimaging studies point towards the frontal areas as neuroanatomical correlates of the CI. However, two main reasons limit the emphasis on this association. First, correlational studies provide only indirect evidence regarding the localization of CI, which are based on the assumption of a direct relationship between cognitive tests and brain areas, or on the anatomical differences across types of dementias. Second, the only imaging study assessing CI (Kwon et al., 2016) has been focused on the tendency to approach the model in normal participants and patients with AD, limiting the possible generalization of the results.

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Table 1: Summary of the single case studies with CI

AUTHORS	DIAGNOSIS	CIB	CA	MEMORY	VISUOSPATIAL	LIMB APRAXIA	FINGER AGNOSIA	VISUAL AGNOSIA	LEFT/RIGHT DEFICITS	AGRAPHIA	ACALCULIA	OTHER DEFICITS
Mayer Gross 1935	Carbon monoxide intoxication (n=1) dementia (n=5)	Graphic copying Writing Gesture	√ (n=6)	√ (n=6)	√ (n=2)	√ (n=3)	√ (n=6)		√ (n=4)	√ (n=5)	√ (n=6)	
Muncie 1938	Dementia	Graphic copying (Overlap)	√	√	-	x	√	x	x	√	-	Echolalia, echopraxia perseverations,
Lhermitte & Mouzon, 1941	Stroke in left occipital lobe	Graphic copyig	√	x	√	x	√	x	x	x	x	
Stengel & Vienna, 1944	Eclampsia Epilepsy	Writing	√	x	√	x	√	x	√	√	√	Simulanagnosia, difficulty in localization of object in space
De Ajuriaguerra et al., 1949	Carbon monoxide intoxication	Graphic copying Writing Gesture	√	√	√	√	√	x	x	√	√	
De Renzi, 1959	Alzheimer's Disease	Graphic copying	√	√	x	x	√	x	√	√	√	Alexia, hemianopia
Pavan, 1966	Pre-senile dementia	Graphic copying	√	x	x	x	x	x	√	√	x	Dressing apraxia, topographic disorientation
Kuroiwa et al., 1967	Carbon monoxide intoxication	Graphic copying	√	√	-	-	x	√	x	√	√	Alexia
Cipollotti & Denes, 1987	Arteriosclerosis	Graphic copying	√	√	-	√	-	-	x	√	-	
Grossi et al, 1996	Right hemisphere stroke	Graphic copying	√	x	√	-	-	-	-	-	-	
Kwon et al., 2002	Corticobasal degeneration	Gesture imitation	√	√	-	√	-	-	-	√	-	Bradykinesia, dressing apraxia, poor phonemic fluency, grasp reflex
Suzuki et al., 2003	Bilateral parietal lobe atrophy	Gesture imitation Writing	√	√	√	-	-	x	-	√	-	
Conson et al., 2009	Corticobasal degeneration	Graphic copying	√	x	√	√	-	-	-	-	-	Poor inhibition of automatic response, Utilization behaviour
McIntosh et al., 2008	Alzheimer's Disease		√	√	√	√	-	-	-	√	-	Neglect

√ Symptom present; x symptom absent; - symptom not tested

Table 2: Summary of the group studies case studies with CI

AUTHORS	MODEL TO COPY	SCORING PROCEDURE OF CIB	SAMPLE	FREQUENCIES
De Ajuriaguerra et al., 1960	Various shapes	Presence/ absence	21 patients with dementia (Probable AD)	7 (33%)
Piercy et al., 1960	Cube copying task	Presence/absence (Overlap CIB)	18 left brain damaged 24 right brain damaged	6 (33%) 2 (8%)
Gainotti & Tiacci, 1970	7-figures task (Spinnler & Tognoni, 1987)	Presence/absence (Overlap CIB)	100 left brain damage 100 right brain damage	5 (5%) 10 (10%)
Gainotti, 1972	7-figure task (Spinnler & Tognoni, 1987)	Qualitative scale: Scrawl, Contour, Transport, Unsettled lines (Overlap subtypes) & Near CIB	132 patients with dementia 200 focal brain damaged	36(27%) [23 Overlap subtypes – 13 Near] 15(7%) [3 Overlap subtypes – 12 Near]
Grossi et al., 1978	7-figures task (Spinnler & Tognoni, 1987)	Presence/ absence of CIB	21 AD 11 Senile dementia 20 Huntington's chorea 25 Multi infarct dementia 27 Cerebral atrophy 4 Pick type dementia 2 Normal pressure hydrocephalus 108 normal adults	8 (38%) 2(19%) 0 0 0 0 0 0
Gainotti et al., 1992	star, cube, house (graphic copying with and without landmark)	Presence/absence (Overlap CIB)	41 AD 34 VaD 50 older adults	9(22%) 2 (6%) 0
Rouleau et al., 1996	Clock copying task	Presence/ absence of CIB (Overlap CIB)	33 AD	2 (6%)
Gainotti et al., 1998	Star, cube, house	Presence/ absence of CIB (Overlap & Near combined)	49 AD 14 progressive supranuclear palsy 26 depressive pseudo-dementia 35 Parkinson disease +dementia 43 multi-infarct dementia 30 older adults	15 (31%) 1 (7%) 1 (4%) 0 3 (7%) 0
Gragnaniello et al., 1998	Overlapped pentagons of MMSE	Presence/ absence of CIB	37 AD	6 (16 %)
Lorenzo-Otero, 2001	9 shapes	Presence/ absence of CIB (Overlap & Near combined)	82 AD 26 older adults	25 (30%) 0
Kwak, 2004	Luria's figure	Overlap, Adherent & Near CIB (Clustered on the distance between end points of copy and model with respect to controls)	98 AD 48 Subcortical VaD 22 older adults 30 young adults	41 (42%) 11 (22%) 2 (9% near) 0
Lee et al., 2004	Luria's figure	Presence/ absence of CIB (Slop of the drawing)	36 AD	13(36%)
Chin et al., 2005	Luria's figure	Presence/ absence of CIB (Slop of the drawing)	55 AD 39 VaD 38 Older Adults	18 (33%) 10 (26%)
Gasparini et al., 2008	10 geometrical shapes (Benton test)	Presence/ absence of CIB	41 AD 15 FTD (fronto-variant)	1 (2%) 1 (7%)
Ambron et al., 2009a	Square, diamond and multipart figure (Milan Overall Dementia Assessment)	Overlap & Near CIB (<10 mm)	797 AD	343 (43%) [179 Near – 102 Overlap - 62 both CIB]
Ambron et al., 2009b	Square, diamond and multipart figure (Milan Overall Dementia Assessment)	Presence/ absence of CIB (Overlap & Near combined)	71 FTD 812 AD	
Ambron et al., 2012	Rey Figure (Caffarra et al., 2002)	Overlap & Near CIB (<10 mm)	154 MCI	33 (21%) [27 Near – 6 Overlap
Serra et al., 2009	Freehand copying task (Carlesimo et al., 1996)	Presence/ absence of CIB (Overlap CIB)	382 AD	39 (10%)
Grossi et al 2014	Overlapped pentagons of MMSE 7-figures task (Spinnler & Tognoni, 1987) Rey Figure (Caffarra et al., 2002)	Overlap & Near CIB (<10 mm)	44 AD	26 (59%) [5 Near – 21 both types]
De Lucia et al 2013	Overlapped pentagons of MMSE 7-figures task (Spinnler & Tognoni, 1987) Rey Figure (Caffarra et al., 2002)	Overlap & Near CIB (<10 mm	64 AD	39 (61%) [16 Near –3 Overlap- 20 both types]
Grossi et al 2015	7-figure task (Spinnler & Tognoni, 1987) Rey Figure (Caffarra et al., 2002)	Overlap & Near CIB (<10 mm)	31 FTD (behavioural variant)	12 (38.7%) [8 Near – 4 Overlap]
De Lucia et al 2014	20-figures (Conson et al 2009)	Overlap & Near CIB (<10 mm)	63 VaD 70 AD	24 (54%) [18 Near – 6 Both] 54 (77 %) * [12 Near 42 Both]
De Lucia et al., 2015	7-figures task (Spinnler & Tognoni, 1987)	Overlap & Near CIB (<10 mm)	100 Parkinson Disease	50 (50%) [46 Near –2 Overlap- 2 Both types]
De Lucia et al., 2016	7-figures task (Spinnler & Tognoni, 1987)	Overlap & Near CIB (<10 mm)	27 patients with focal lesions 25 healthy controls	18 (60%) [15 Near – 3 Both] 0

* Significant differences in the frequencies between groups;

Figure Captions

Figure 1. CI shown by an artist with dementia (from Mayer Gross, 1935). From the left: patient's performance in the graphic copying of a face, drawing a train from memory, writing (CI is evident in the superimposed letter) and arithmetic calculations. In all these examples, the dotted lines represent the model and the unbroken lines the patient's performance.

Figure 2. CI in Luria's figure (from McIntosh et al., 2008).

Fig1

Fig 2