A lateralized bias in mental imagery: Evidence for representational pseudoneglect

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Abstract

One hundred right-handed healthy individuals were asked to imagine a familiar scene (the Piazza del Duomo, Milan) from two opposite viewpoints and report what they could see. For elements that should be visible from the participants’ viewpoint, more elements were reported from the left side of the image than from the right, irrespective of view. These results establish that there is a lateralized bias in reporting the details in mental images—representational pseudoneglect. This bias is in the opposite direction and significantly smaller than the bias seen in individuals with representational neglect following right hemisphere damage. Representational pseudoneglect appears analogous to perceptual pseudoneglect and the two may share an underlying mechanism. The results are interpreted as indicating that pseudo-representational neglect arises as the result of a bias in the allocation of attention to the imagined scene.

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Patients with neglect often fail to report stimuli, which are present on the side of space opposite the site of the brain lesion. Neglect can affect both the immediate, observed environment (referred to as perceptual neglect), or the mental representation of space. Patients with the representational form of neglect are unable to report details on the left of an imagined, familiar scene.

The seminal demonstration of the representational form of neglect was described by Bisiach and Luzzatti[4]. They reported two patients who neglected information from both the left-hand side of their environment and from the left-hand side of mental images. When the patients were asked to imagine and then describe a familiar scene, the Piazza del Duomo in Milan, they systematically reported far fewer landmarks on the left-hand side of the image than landmarks on the right. Critically, this neglect of landmarks on the left of the image occurred irrespective of whether the imagined viewpoint was from the steps of the cathedral or from the opposite side of the square looking towards the Cathedral. Elements that the patients showed no awareness of from one view point were accurately reported when the patient took the opposite perspective.

Neurologically intact individuals also show a spatial processing bias (for review see [16]), which has been referred to as ‘Pseudoneglect’ [5] to reflect the fact that the errors are in the opposite direction (and are significantly smaller) than those made by patients with right hemispheric damage who manifest unilateral spatial neglect[15]. This leftward bias has been observed in healthy participants under a host of experimental conditions and interpreted by various accounts [20,24], including evolutionary ones [25]. While the bias observed in neurologically intact individuals is small, it can still have behavioural consequences [28].

To date, and to our knowledge, no one has explicitly examined whether neurologically intact adults demonstrate a representational bias in visual imagery similar to perceptual pseudoneglect. Some hints can be gleaned from the literature that normal adults will demonstrate a lateralized imagery bias. The results reported by Bisiach et al. [3] for 41 control participants suggest a left-side
advantage for the report of elements from the visual image of the cathedral square. However, Bisiach et al. did not explicitly test for this effect. Similarly, a small but non-significant left side advantage for the correct recall of elements by control participants can be seen in the results reported by Denis et al. [11] in their memory-after-perception condition. However, in the Denis et al. study, control participants were performing at near ceiling for both left and right side elements and this may have prevented the emergence of a significant difference. In addition, lateralized biases in normal adults are of small size and only 15 control participants were included in the Denis et al. study, consequently it may have been difficult to detect a significant bias.

Results by Rousseaux et al. [27] for a task requiring participants to report cities from an imagined map of France, have also hinted at the possibility of representational pseudoneglect. However, Bartolomeo et al. [1] found no evidence of such asymmetry in either accuracy or response times when measuring performance in a similar task. In addition, Načić et al. [23] tested normal individuals with a computerised version of the Corsi Blocks task, in which participants were asked to remember a series of cubes simultaneously presented on the screen. They found that participants omitted more cubes presented to the right than the left side. A similar leftwards bias was observed in spontaneous turning behaviour while walking [13,22]. Moreover, in a recent paper Urbanski and Bartolomeo [29] reported in passim (see their Fig. 2) that healthy controls show a small leftward deviation in an imagery bisecting task while neglect patients show the expected rightward deviation. Finally, Cocchini et al. [8] reported some evidence that pseudoneglect could be observed for the “back space”, i.e., the space behind the participant’s shoulders.

The procedure used by Bisiach and Luzzatti [4] to examine representational neglect lends itself well to testing normal adults. In addition, using the same procedure on a sample of participants from the same population allows closer comparison with the original findings on representational neglect. Therefore, in the following study a large sample of right-handed participants, all of whom were familiar with the cathedral square in Milan, were tested using the Bisiach and Luzzatti procedure. The aim of the study was to investigate whether or not there would be a small but significant bias with participants reporting more elements from the left side of the visual image.

The study was carried out on 100 right-handed participants (37 males and 63 females) with a mean age of 49.80 years (range: 20–86, S.D. = 17.41) and a mean number of years of education of 11.90 (S.D. = 4.66). To be included in the study the participants had to be Italian, living in Milan, be familiar with the Cathedral Square in Milan and score above 26 in the Mini Mental State Examination [12]. None had taken part in any previous study involving imagery of the cathedral square.

The procedure was similar to that reported by Bisiach and Luzzatti [4]. Participants were asked to provide a verbal description of the cathedral square in Milan, which is a very large, squared Piazza (Piazza del Duomo). Half of the participants were asked to imagine themselves facing towards the front of the cathedral and then to describe the square. When they had finished their description, for each item the participant had reported, the experimenter asked whether the item appeared on the right-hand or left-hand side of the square. Participants then undertook a standardized battery of verbal neuropsychological tests (spelling tasks, description of a scene and recall of the same scene from memory), which lasted 40 min and prevented verbal rehearsal of the details of the square. The imagery procedure was then repeated with the participant asked to imagine the square from the opposite vantage point, i.e., facing away from the cathedral. The remaining participants undertook the imagery tasks in the opposite order, i.e., first imagining the square as if they were facing away from the cathedral and secondly, as if facing the front of the cathedral.

Elements reported by the participants were classified as “seen” if they would actually be visible in an accurate image of the square from the participant’s vantage point and “non-seen”, if the reported element was present in the square and lateralised but would not be visible from the participant’s vantage point. In addition, a list of ‘correct’ elements was constructed by considering all the elements recollected by 15 “judges”, by following a close inspection of the square, and by studying aerial maps of the area. For “seen” elements (from the viewpoint facing the Cathedral) there were 22 possible elements on the left and 13 on the right. For “non-seen” elements, there were 7 elements on the left and 7 on the right. Elements reported by the participants were classified as correct if they appeared on the list pre-selected by the authors.

For each participant, laterality quotients (LQ) were calculated for accurately reported seen and non-seen elements according to the formula proposed by Bisiach et al. [3]: \( R - L / R + L \times 100 \), where \( R \) and \( L \) are the sum of right- and left-sided details of the square given in the description from the two opposite vantage points, respectively. A negative LQ represents a bias to report items from the left and a positive LQ the opposite bias, reporting more items from the right.

For elements that could have been seen from the two viewpoints, the mean LQ was \( -3.25 \) (S.D. = 14.14) and a single sample t-test indicated that this LQ was significantly different from 0 (\( t(99) = -2.30, p = .02 \)). For elements reported that could not have been seen from the participants viewpoints, the mean LQ was 8.47 (S.D. = 59.40) and a single sample t-test indicated that this LQ was not significantly different from 0 (\( t(99) = 1.37, p > .05 \)). LQ was also significantly correlated with age. For items that would have been visible from the two vantage points there was a significant negative correlation with participant age (\( r = -0.29, N = 93, p < .05 \))—as participant age increased LQ tended to become more negative. For items that would not have been visible there was a positive correlation with participant age (\( r = 0.26, N = 93, p < .05 \))—as participant age increased LQ became more positive.

Similar results were obtained considering the raw scores. Summing across vantage points, for participants who described the scene facing towards the cathedral first, the mean number of seen elements reported on the left-hand side of the square was 10.16 (S.D. = 4.81) compared to 9.49 (4.26) for elements on the right-hand side of the square. For participants who described the scene facing away from the cathedral first, the mean number of seen elements reported on the left-hand side of the square...
was 9.76 (S.D. = 4.43) compared to 9.25 (4.27) for elements on the right-hand side of the square. Participants reported significantly more elements from the left-hand side of the image than from the right ($F(1, 98) = 5.55, p = .02, \eta^2_p = .05$). The order in which participant imagined the square did not affect the number of items recalled ($F(1, 98) < 1$, NS) and there was no order by side interaction ($F(1, 98) < 1$, NS).

For non-seen elements, for participants who described the scene facing towards the cathedral first, the mean number of seen elements reported on the left-hand side of the square was 2.49 (S.D. = 2.23) compared to 2.82 (2.18) for elements on the right-hand side of the square. For participants who described the scene facing away from the cathedral first, the mean number of seen elements reported on the left-hand side of the square was 1.94 (S.D. = 1.88) compared to 2.10 (1.78) for elements on the right-hand side of the square. There was no significant difference in the number of elements reported from the left and right hand sides of the square ($F(1, 98) = 1.61, p > .05$). The order in which participant imagined the square did not affect the number of items recalled ($F(1, 98) < 3.20, NS$) and there was no order by side interaction ($F(1, 98) < 1$, NS).

An examination of the LQs indicated that six participants had LQs that were over 1.96 standard deviations from the group mean, three of these cases had large positive LQs (33.33, 27.27, 25.00) and the remaining cases, had large negative LQs (−44.44, −42.86, −42.86). In the current sample, four participants had laterality quotients that were within 1 standard deviation of the mean LQ reported for patients with representational neglect by Bisiach et al. [3]. Using the procedure developed by Crawford and Garthwaite [9] for comparing single cases with a small normative sample, in this case the Bisiach et al. sample of patients with representational neglect (mean LQ = 56.35 ± 37.2), the LQs of all four of these participants could not be considered different from the patient group (all $t$-values $< 1$).

There were a total of 21 transposition errors when reporting seen and non-seen elements, i.e., reporting elements from one side of the square as being on the other. There were 13 transposition errors for seen elements and 8 for non-seen elements. These transposition errors were not distributed equally. For seen elements, 11 of the 13 errors involved a right transposition (i.e., an item that should have been reported on the left of the square being reported on the right), participants made significantly more right transposition errors ($\chi^2 = 6.23, df = 1, p = .013$). For non-seen elements there was no significant difference in left and right transposition errors ($\chi^2 = 2.00, df = 1, p = .157$), six of the eight errors involved a left transposition.

The aim of the present study was to investigate whether neurologically intact individuals demonstrate a lateralized-bias in describing mental images. As anticipated, the results for the elements of the scene that individuals should be able to see in their images (seen elements) show that participants are better able to report items on the left of an imagined scene. While statistically significant, the size of the bias observed, even with a large sample, was very small. This *representational pseudoneglect* is in the opposite direction and, as would be hoped, much smaller than the bias observed in patients with representational neglect following right hemisphere lesions (e.g. [3]).

For items that would be visible in the imagined scene, the size of the lateral bias was related to the age of participants: older participants tended to show a greater bias in reporting items from the left of the scene than did younger participants. This result contrasts with results from line bisection. While in general, neurologically intact adults demonstrate a small but significant tendency to bisect horizontal lines to the left of true centre, the magnitude and direction of this bias is moderated by age: increasing age resulting in a more rightward bias [16].

A similar bias was not observed for elements that were present in the square but would not have been visible from the participant’s vantage point. In this case the LQ was not significantly different from zero indicating no lateral bias and while there was a significant correlation between age and LQ this indicated a positive relationship—as the age of the participant increased there was a tendency to report more items from the right of the scene. These findings add weight to the hypothesis that during the task participants actively inspecting a mental image rather than relying on a stored list of possible elements.

Within the literature one widely supported explanation for the occurrence of perceptual pseudoneglect is the activation–orientation hypothesis [17,18,26]. The activation–orientation hypothesis proposes that an asymmetrical increase in hemispheric activation results in a contralateral shift of attention. So in a task such as line bisection, which as a visuospatial task would in all likelihood result in preferential activation of the right hemisphere, attention will be shifted to the left and as a consequence the extent of the left half of the line is overestimated. The result of the overestimation is that the subjective midpoint of the line is perceived to be left of true centre. A similar explanation holds for other size judgement tasks. For example, an ellipse presented in left hemi-space is perceived to have a larger horizontal extent than the same ellipse presented in right hemi-space [7]. The attentional account has also been used to explain both representational and perceptual forms of neglect following neurological injury (e.g. [14,17,18,21]).

The attention-based activation–orientation hypothesis offers an explanation of the current results. Greater activation of the right hemisphere caused by the visuo-spatial nature of the imagery task may therefore result in a left shift in attention and in consequence a greater tendency to report items from the left of the visual image.

An alternative explanation for the current results that is not based on the biased allocation of attention can be found in the neuropsychological literature on representational neglect. This alternative explanation suggests that representational neglect reflects a lateralized impairment at some level working memory [10]. Applying the visuo-spatial representation hypothesis to the current results would imply that in normal right-handed adults the representation generated of the Cathedral Square is more detailed for the left side of imaged scene.

Debora Sala et al. [10] have presented evidence suggesting that, at least for representational neglect following brain lesion, a representational explanation is more parsimonious. In their study, patients with representational neglect were shown two-by-two arrays of novel objects, the array was removed and subjects...
were required to recall the elements from either the perspective they had been shown or from the reverse perspective. Della Sala et al. argued that the requirement to perform the task from the reverse perspective required the mental rotation of the contents of visuo-spatial working memory. The results indicated that when asked to recall the elements from the perspective from which the elements had been viewed, patients showed a pattern consistent with representational neglect—accuracy was greater for elements on the right-hand side of the presented arrays. In contrast, when asked to report the elements from the reversed perspective accuracy for right and left elements was equivalent but both were significantly lower than for elements on the right recalled from the original perspective. Della Sala et al. argue that this pattern of performance cannot be explained by biases in attention to aspects of the image. The results appeared more consistent with the view that a functional attentional system had access to an impoverished visuo-spatial representation and that this impoverished representation was mentally rotated to provide the opposite perspective there was no further loss of information (see also [6]).

Bisiach [2] has suggested that attentional explanations [17] and representational explanations [10] of neglect (and by extension pseudo-neglect) are logically indistinguishable and in the current study both could be used to account for the observed pattern in the data. The extent to which the results reported by Della Sala et al. [10] generalise to neurologically intact individuals remains moot and in the absence of these further data the issue of whether the current results are best accounted for by an attentional or representational explanation cannot be settled. However, based on the existing literature on pseudo-neglect, the most parsimonious explanation remains that of a lateralised bias in the allocation of attention.

Finally, the data indicated that individuals with extreme laterality quotients (i.e., greater than 1.96 standard deviations from the mean) can be found in the neurologically intact populations. These outlying individuals can fall equally at either end of the distribution, demonstrating either extreme right or extreme left biases, and they are from no single age group (young or elderly). In addition, if those individuals who demonstrate an extreme right bias are compared to the distribution of laterality quotients for participants with representational neglect then they do not appear statistically different. Though it is important to caveat this by saying that the Bisiach et al. [3] patient sample that served as a reference group is very small and as a result the comparison lacks some statistical power. That said the fact that individuals with quite extreme values can be observed in an apparently neurological intact sample raises questions concerning the diversity in the mechanisms that people may employ when asked to construct mental images as well as potential individual differences in the basic cognitive functions needed to perform imagery tasks. In this regard, Marcel et al. [19] have shown very interesting findings. When stimuli are presented to both sides of the body or of space and when healthy people are asked to attend to those on one side, a subgroup of them experience the stimulus presented to the unattended side as if it was presented on the attended side. This happens in the same people in different sensory modalities of presentation: touch, hearing and vision. The implication is that some normal people could be susceptible to the spatial perception biases previously thought to be produced only by brain damage. Whether or not these would be the same people who prove to be more susceptible to overt neglect if victim of a brain damage is an interesting though, at this stage of knowledge, gallant speculation.

In summary, neurologically intact right-handed adults asked to form a mental image of a familiar scene show a significant representational bias showing an impoverished awareness of elements on the right-hand side of a mental image. This representational bias is in the opposite direction and significantly smaller than the bias found for patients with representational neglect following lesions to the right hemisphere. This pattern mirrors the well established finding of a small lateral bias in perceptual tasks such as line bisection and demonstrates that pseudoneglect can be found in neurologically intact individuals in a representational task.

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References