Visually misguided reaching in Balint’s syndrome

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Received 23 February 1998; received in revised form 18 August 2000; accepted 17 November 2000

Abstract

A patient with bilateral parietal damage leading to Balint’s Syndrome was tested on his ability to reach to, and to describe the locations of visual targets. RM was better at reaching to targets than he was at describing the locations of the same targets. Moreover, he was better at reaching to targets when he could not see them, compared to when he was reaching with visual guidance. In a final experiment, we found that RM showed strong inhibition of responses to non-target items, even though he had a poor representation of their location in depth. As a result of intact inhibition and impaired depth representation, he ignored both target and non-target items in a given direction. These results suggest that in RM a disturbed visual representation of space disrupts an otherwise relatively intact reaching control system. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Balint’s syndrome; RM; Control system

1. Introduction

The syndrome that results from bilateral lesions to the parietal lobes is typically named for Reszo Balint, although many patients subsequently described as having this syndrome may differ somewhat from the first patient he described in 1909 [2,16]. Patients with this syndrome have a number of attentional deficits, including gaze ataxia, neglect for peripheral stimuli, and simultanagnosia [8,13,14,23]. The parietal lobes are thought to be responsible for the allocation of attention to the contralateral side of space, and the disengagement of attention from ipsilateral space [17]. Damage to one parietal lobe leads to contralesional neglect, since attention cannot be directed to that side. It is straightforward to see how bilateral parietal lesions might be expected to lead to an inability to direct attention to anywhere except the center of gaze. This may lead to fixity of gaze and fixity of attention on a single central item.

A cluster of symptoms shown by patients with Balint’s Syndrome can be thought of as disturbances in the representation of space. Patients may have difficulty detecting the direction of motion of visual objects, and may have severely impaired depth perception. They typically have poor ability to reach for objects under visual guidance (so called optic ataxia [2]) although they may be able to correctly reach out and touch parts of their body if their eyes are closed. Optic ataxia may be seen in patients with unilateral lesions [16,21], and in some cases may be seen with just one arm and not the other [2,16]. However, it has been suggested that the misreaching seen in neglect may be different to optic ataxia [12]. Karnath et al. [12] showed that patients with neglect were able to accurately reach to targets with little deviation of trajectory to the ipsilesional side, suggesting that optic ataxia is not associated with neglect. However, the same patients show a deficit in exploratory visuospatial behaviors. This dissociation has been recently challenged by the demonstration that neglect patients do show a deviation of reaching trajectories that appears to be due to a disturbed visual representation [11].

The classic clinical demonstration of optic ataxia is by showing that the deficit in reaching under visual guidance to external targets is far greater than (non-visual) reaching to parts of the body. Unfortunately this dissociation confounds two factors—whether there is vi-
sual guidance and whether the reaching is to extrapersonal or personal space. Therefore, optic ataxia can be interpreted either in terms of whether visual guidance is involved, or whether reaching is to personal or extrapersonal space. The purpose of the present study is to produce an unconfounded interpretation of the dissociation that marks optic ataxia.

The typical interpretation of optic ataxia can be termed the visual guidance hypothesis. According to this view, reaching under visual guidance is disrupted, but reaching under proprioceptive guidance is unimpaired. The counter hypothesis may be termed the allocentric view. According to this allocentric view, the difficulty in reaching to extrapersonal space under visual guidance is not related to the visual guidance but purely because the targets cannot be specified in terms of the surface of the body.

These two interpretations of optic ataxia make different predictions. According to the visual guidance view, reaching to all targets (whether in personal and extrapersonal space) under visual guidance is impaired, yet reaching without vision will be spared. Such a disruption of reaching due to impaired visual representations may be predicted based on the tendency of vision to override other forms of representation (see also [10]). Conversely, the allocentric view suggests that reaching to extrapersonal space will be impaired regardless of whether or not this is visually guided, while any reaching to personal space will be spared.

In this study, we examined the visuospatial ability of a patient with bilateral parietal damage and resulting optic ataxia, in order to dissociate the visual representations of external space from the ability to reach. In this way we were able to show that the principal source of his deficit lay in a disrupted visual representation, rather than in the control of reaching per se.

2. Method

2.1. The patient

RM is a 56-year-old man who had suffered a right parieto-occipital stroke 2 years and 9 months before testing. This produced transient left hemiparesis and left visual neglect, but only mild residual disability. Nine months before testing he had a second stroke (due to cardiac embolus) in the left parieto-occipital area. A CT scan (see [4]) showed bilateral parietal infarcts together with a right cerebellar infarct. The cortical infarcts extend into the superior parietal lobule on both sides. RM remained lucid and ambulatory with intact language and memory, and independence in his daily activities.

On testing, his visual acuity was good, and his visual fields were intact on confrontation. On clinical exam, eye movements to command were largely intact and optokinetic nystagmus preserved, but he had great difficulty following moving objects with his eyes. He had great difficulty in seeing or reporting more than one object at a time, and could not report which of two objects was closer to him. Although RM was above chance at judging whether single objects were moving toward or away from him, he did not blink to a visual threat. Reaching under visual guidance was inaccurate, but reaching for parts of his own body with eyes closed was accurate. RM gave his informed consent and was paid $40 for his participation in the present study which took place in two testing sessions.

2.2. Apparatus and stimuli

The apparatus is a 51 × 51 cm stimulus board consisting of 13 stimulus keys, shown drawn to scale in Fig. 1. In all the testing carried out on RM only 10 of these keys—the closest start key and the central 9 keys—were used. Therefore, only these 10 keys are shown in the schematics in this paper. All keys were translucent and could be illuminated red (target) or green (distractor) by a bicolor LED located beneath them. The board was tilted towards the participant at a 35° angle. The key closest to the participant (the ‘start key’) was illuminated with a yellow LED. Beneath each key was a microswitch that detected a slight touch on the key. The onset of LEDs and detection of closure of the microswitches was accurate to within less than 1 ms. The stimulus board was interfaced with an AST laptop computer that recorded target and distractor positions, response times (RTs) and errors. The responses of young and older adults using this apparatus have been well documented [18,20].

Image 1. A schematic of the selective reaching apparatus used in this study. There were two start keys (near or far) and nine targets keys. The target keys could be illuminated red (as targets) or green (as distractors) by means of bicolor LEDs within the keys. The keys detected a slight touch by means of a microswitch. The apparatus was controlled by computer. Feint outlines show the locations of three keys not used in this experiment.
2.3. Procedure

The sequence of events within each task was explained to RM at the beginning of that task. All trials were initiated by RM pressing the start key on the reach apparatus. After a delay of 500 ms, one of the keys on the board was illuminated red as the target key. In tasks 1, 2, 4 and 5, RM was instructed to reach as quickly as possible to touch the target key. RM was encouraged to rest at any time, although he never chose to exercise this option. No feedback on performance was given during the testing, apart from general encouragement. In every experiment, an analysis of the reaction times to perform reaching actions showed that none of the differences between conditions of interest approached significance. Therefore, all data presented relate to the patterns of errors made by this patient.

The nine locations of possible target items on this apparatus are described below as three rows, and three columns. Errors are sorted by whether or not they are on a key in the same row or column as the target. All comparisons of the frequency of different types of errors are carried out by means of $\chi^2$-tests [22], with df = 1, except where noted.

3. Experiment 1

In this first experiment we test the ability of RM to reach with his preferred (right) hand to a visually defined target.

RM sat facing the reaching board that was directly in front of him. His attention was drawn to the center key, and was asked to maintain fixation on this key. Given that he displayed considerable fixity of gaze, maintaining fixation presented no problem to him. RM pressed the start key to begin each trial. After a delay of 500 ms, a single target key was illuminated red on the board. He was instructed to reach to and touch this target as quickly as possible without making errors, using his right (preferred) hand. The target key remained illuminated until touched, but if no response had been made in 5 s, the target key was dimmed, and a new trial began. A total of 288 trials were presented in this and all other experiments except where noted otherwise, with every location on the board being shown 32 times.

3.1. Results

RM made many errors on this task, typically errors of commission in which he pressed a key that was not illuminated. On just three trials he failed to respond to the target. The commissive errors are shown in Fig. 2b, and could be of three types. The response could be to press a key that was located in the same direction but at a different depth (depth error), to press a key that was at the same depth (i.e. within the same frontoparallel plane) as the target but in a different direction, so called direction errors, or to press a key that was both at a different depth and a different direction (both errors). The errors of these types that RM made on this task are shown in Fig. 2b with the location of the target key sorted according to column (left side of figure), or sorted according to row (right side). This figure shows that, regardless of the location of the target key, RM made more errors of depth than errors of direction ($\chi^2 = 5.0$, $P < 0.03$).

Another way of looking at the errors made is to consider them as a measure of the similarity (or confusability) between the different locations. If we take the number of incorrect responses made on one key, when the target was at another key as a measure of similarity between those keys, we can derive a map of the patient’s internal representation of the different locations. A matrix of the numbers of confusions between every pair of keys was scaled using multi-dimensional scaling (MDS [22]) to produce a diagram of the internal representation shown in Fig. 3b. This figure shows how RM represents the locations of the nine keys. It can be seen that his representation is generally intact, being topologically equivalent to the actual arrangement of the keys. However, what is very obvious is that there is considerable compression of depth, because he finds position highly confusible along the depth dimension.

These results show that RM displayed optic ataxia—the inability to reach to a target under visual guidance. Although, interestingly, on many occasions, RM made the comment that he did not know where the target was, even though he was able to reach directly and rapidly to it. This suggested that his appreciation of the target locations may have been worse than his ability to reach to them. This observation suggested Experiment 3, in which we compared the ability of RM to reach to a target to his ability to simply say where the target was.

This inability to reach under visual guidance is frequently confined to reaching with just one hand, and not the other. Indeed, in Balint’s [2,3,9] famous case, optic ataxia was only seen when the patient reached with his right hand. Optic ataxia that is confined to reaching with one hand, or may be confined to targets in one visual field may be seen in patients with unilateral lesions [10,21]. Therefore, prior to further dissection of RM’s deficit, we tested his ability to reach with his non-preferred hand in order to determine whether his optic ataxia was specific to one hand or not.
Fig. 2. The proportion of errors made: (a) in Experiment 2; and (b) in Experiment 1, as a function of the location of the target key. In all cases errors of depth are more frequent than errors within the frontoparallel plane.

4. Experiment 2

This experiment was carried out to determine whether RM’s optic ataxia was confined to reaching with his right hand. All instructions and aspects of the task were the same, except that RM was asked to use his left (non-preferred) hand, and that there were now only 144 trials (16 per key). The results, shown in Fig. 2a, are essentially the same as those for reaching with his preferred hand, except that he makes a slightly higher error rate. This overall difference in error rate was not significant ($\chi^2 = 0.2$).

Taken together, Experiments 1 and 2 suggest that the optic ataxia of RM may be due to a deficiency in visuospatial representation that is not a motor control problem associated with one hand or the other. However, it could be argued that the two (near symmetric) lesions of RM each damaged hand-specific reaching control. In other words, the hand-independence of his deficit might be merely an accident of paired lesions. Therefore, it was necessary to attempt to directly dissociate the visuospatial ability of RM from his reaching ability.

Fig. 3. Confusability of the nine key locations in space, shown in (a); as evidenced by (b) the reaching errors of Experiment 1 and (c) the verbal report errors of RM in Experiment 2. The diagrams (b) and (c) were produced by considering all the errors of commission of RM as similarity measures that were then subjected to MDS.
5. Experiment 3

Experiments 1 and 2 show that RM displayed optic ataxia when reaching with either hand. In this experiment, we test whether an impaired perception of target location could be the source of his reaching errors. In other words, it is possible that RM was relatively unimpaired in his ability to control reaching, but given a poorly specified target, he reached inaccurately. We tested this, but requiring him only to say where a target was. RM was instructed to press the start key to begin each trial, and as before a single red key was illuminated after a delay of 500 ms. However, he was instructed to name the location of the illuminated target, but not reach to it. He was instructed to name the target using the words LEFT, CENTER, RIGHT combined with BACK, MIDDLE, FRONT. He was asked to describe these location descriptors, back to the experimenters, and he displayed errorless appreciation of their ordinal values. He was instructed that he had to name a location, and so errors of omission were not possible. As soon as RM had given two descriptors of the location of the illuminated key (e.g. ‘LEFT, FRONT’), the experimenter pressed the space bar on the computer, which provided an estimate of the response time. At this point the illumination of the target key was turned off. RM’s verbal reports were then entered into the computer by the experimenter for later analysis. On four occasions, RM corrected himself after first giving a location. Three of these occasions represented a mirror reversal (e.g. ‘LEFT FRONT… I mean… RIGHT FRONT’). On all four of these occasions the corrected location was entered into the computer.

5.1. Results

RM made very many more errors at this task compared to Experiments 1 and 2, as can be seen from an inspection of the data shown in Fig. 4b. For comparison, the data for Experiments 1 and 2 are pooled together and shown in Fig. 4a. As in Experiment 1, he made many more errors in depth that errors at the same depth ($\chi^2 = 9.2, P < 0.005$). However, in addition he made many more depth errors in this experiment than in Experiment 1 ($\chi^2 = 51.9, P < 0.001$). Furthermore, RM made more of the other types of errors (i.e. direction errors and errors in both dimensions) in this experiment than in Experiment 1 ($\chi^2 = 19.6, P < 0.001$). These results suggest that RM’s appreciation of the location of targets was worse than his ability to reach to these same targets. In order to understand whether

![Graph](image)

Fig. 4. The proportion of errors made: (a) for reaching in Experiments 1 and 2 (collapsed together); and (b) for verbal report in Experiment 3, as a function of the location of the target key. In all cases errors of depth are more frequent than errors within the frontoparallel plane. Furthermore, there are more errors made when RM is asked to verbally report the target location than when he is asked to reach to it.
6. Experiment 3

These results suggest that RM's visual perception of space is worse than the spatial representation employed by his motor system. However, it could be argued that in this task, no motor program is produced, since no reaching action is required. In other words, it was never really necessary for RM to produce a representation of the reaching action, or even the location to be reached to, since he knew that he would not be required to reach to the targets. In order to test this possibility, in the next experiment we required RM to describe the location of the target and to reach to that target as soon as he had described the location. If the poor spatial appreciation seen in Experiment 3 were due to the fact that no reaching action needed to be programmed, we would see an improvement in spatial awareness in the next experiment.

6. Experiment 4

This experiment was to test whether the increase in errors seen in Experiment 3 was due to the fact that no reaching action was planned. RM pressed the start key to initiate each trial. As before, a single target key was illuminated after a delay of 500 ms. RM was instructed to say the location of the target in the same manner as the previous experiment, and then to immediately initiate a reaching action to the target, using his preferred (right) hand. It was emphasized that RM should not initiate a reaching action until he had named the target key, and on no occasion did he release the start key until he had made a verbal report. His errors on both aspects (the verbal report, and the reaching action) of the task were scored exactly as before.

6.1. Results

The errors made by RM on the verbal and reaching aspects of this task are shown in Fig. 5. As before, he made many more errors on describing the location of the target, than he did in terms of reaching to the targets. Indeed his performance was essentially as be-
fore. RM was far worse at describing location than at reaching to targets ($\chi^2 = 10.5, P < 0.001$). There was no difference in the number of reaching errors compared to Experiment 1 ($\chi^2 = 0.04$, n.s.), nor was there any difference in the number of errors at describing location compared to Experiment 3 ($\chi^2 = 1.4$, n.s.).

Interestingly, errors of reaching and verbal report did not vary independently. That is, occasions when RM made a mistake on reaching were almost always when he had incorrectly described the location. Indeed, there were only two occasions when RM correctly described the location, yet reached incorrectly. This might suggest that the errors of visual perception may be related to errors of reaching, even that they tend to cause errors of reaching. If it is indeed the case that errors of describing the space in a visual manner actually cause errors of reaching, it might be that reaching would be more accurate when description of the space did not occur. In order to test this possibility, we carried out Experiment 5, in which we prevented RM from having any visual representation of the target locations.

7. Experiment 5

This experiment was to test whether the misreaching seen in Experiments 1 through 4 was due to a disordered visual representation of space. In order to test this, we asked RM to reach in the absence of visual input. Therefore, in this experiment, RM was blindfolded, and so was unable to see the visual location of the targets. Instead, he pressed the start key and waited to be instructed of the location of the target key by the experimenter. The experimenter named the target key using the same coding that RM had used in Experiments 3 and 4. So, for example, the experimenter might announce ‘RIGHT FRONT’ as a target location. RM reached out to touch the target keys, and the computer automatically recorded responses.

7.1. Results

RM made few errors at this task. The errors were scored as before and are shown in Fig. 6b. Although
he still tended to make more errors of depth, this trend was not significant ($\chi^2 = 2.4, P = 0.12$). The error rate of RM was reduced compared to Experiment 1, where he had to perform the same reaching action, but under visual guidance ($\chi^2 = 43.3, P < 0.001$). This was also true of the number of depth errors alone ($\chi^2 = 7.9, P < 0.001$). We also tested the ability of RM to reach while blindfolded with his left (non-preferred) hand. These data are shown in Fig. 6a. Unfortunately, RM was unwilling to continue this for more than 108 trials. The data shown in Fig. 6a suggest that even reaching by his non-preferred hand is very much improved by the removal of the disturbed visual representation. However, the small number of trials precludes meaningful statistical comparisons between these data and the data of Experiment 2.

Thus RM was more accurate to reach to targets in extrapersonal space when he did not have access to visual input. These results suggest that RM's visual representation of space was extremely disturbed (as evidenced by his extremely poor ability to describe the location of targets), and that this visual misinformation actually worsened his ability to reach. Removal of the influence of this disturbed visual representation by blindfolding RM led to a marked improvement in his reaching performance.

This experiment shows that the key aspect of RM's optic ataxia is visual perception, and that the issue of whether reaching is to extrapersonal space or personal space is essentially irrelevant. When RM reached to extrapersonal space without visual guidance he showed remarkable accuracy that contrasted with his inability to reach to the same space when he had visual guidance. Further evidence came from less formal testing in which we asked RM to reach out and touch parts of his body with his eyes open. On testing him 10 times in his ability to reach our and touch visible parts of his left arm and upper legs, he showed errors in initial contact point of approximately 12 cm (range 7–22 cm), whereas when asked to reach to the same 10 targets with his eyes closed he was within 3 cm each time. Thus reaching even to personal space may be disrupted by availability of a disturbed visual representation.

It is possible that visual information tended to disrupt RM's reaching by distraction by non-target information. Our final experiment investigated the effects of distractor items on visually guided reaching, to see whether RM was abnormally sensitive to distraction in any way.

![Graph showing error rates in different conditions of Experiment 1 and Experiment 6](image)

Fig. 7. The proportion of errors made by RM in Experiment 6, where he had to reach to a target in the presence of a distractor; (b) with a distractor in a different row and different column to that of the target; (c) with a distractor in the same row as the target; (d) with the distractor in the same column as the target. Note that in (d) the target and distractor are distinguished primarily by different depth, which is the spatial dimension that RM has greatest difficulty with. For comparison, data from Experiment 1 (where no distractor was present), is given in (a).
8. Experiment 6

This experiment is to test the possibility that the increase in error rates seen while reaching under visual guidance was due to an overall increase in distractibility. In this experiment, two keys were illuminated on the response board. One (the target key) was illuminated red as before, and another (the distractor key) was illuminated green. It was emphasized to RM that he should reach to the red target items with his right hand (exactly as he had done in the previous experiments) and ignore the (green) distractor items.

8.1. Results

The errors made by RM were classified as before, but additionally it was noted when he made a response that involved (incorrectly) pressing the distractor key. In fact, RM made such errors very rarely (in contrast, for example, to patients with Alzheimer’s Disease [9]). The pattern of errors made when the distractor item was in a location unrelated to the target were essentially the same as that from Experiment 1 (compare the first and second panels of Fig. 7). Of particular interest is the pattern of errors shown when the distractor was located either at the same depth, but in a different direction, or in the same direction (but at a different depth).

It can be seen from Fig. 7 that the pattern of errors made when the distractor is at the same depth, but in a different direction to the target is very similar to the pattern seen for errors either without any distractors, or with a distractor in an unrelated location. In contrast, the pattern of errors seen when the distractor and target are in the same direction but at different depths, is entirely different ($\chi^2 = 8.6$, df = 2, $P < 0.01$). One possible explanation of these data is that, in attempting to inhibit [19] responses on the distractor item, RM is preventing any responses in the same direction of this distractor. Since the correct (target) response is in this same direction, such a strategy will lead to frequent responses in a different column on the board.

9. General discussion

Our study investigated visual description of space, and reaching with and without visual guidance in a patient with Balint’s Syndrome including optic ataxia. We found that the ability of this patient to reach under visual guidance was superior to his ability to describe the location of visual targets. Since his difficulty in describing visual locations occurred even when a reaching action was required, the planning of an action cannot overcome his difficulty in describing space. Furthermore we found that reaching under verbal instruction but without visual input improved RM’s ability to reach. This was equally true for targets in personal space and those in extrapersonal space. No difference in reaching ability was seen for right (preferred) or left (non-preferred) hand reaching, either for visually-guided or non-visual reaching. Taken together, these results suggest that RM’s disturbed visual representation of space impaired his ability to reach, analogous to the way that an inaccurate (displaced) visual position can ‘capture’ perceived location [7].

When RM was required to reach for visual targets in the presence of visual distractors he displayed another sense in which his action plans were intact, while his visual representations were impaired. When a target and distractor appeared in the same direction, but at different points in depth, RM typically did not respond in that direction, but instead reached in a different direction resulting in an erroneous response. This suggests that he was able to inhibit responses to a distractor item, again suggestive of relatively intact control of action. However, since his visual representation of space was impaired, this inhibition could not be spatially confined to the distractor location but included instead a target location. In avoiding responses to the distractor (evidence of an intact action plan), he inadvertently avoided the target, because of the spatial confusion of target and distractor in his disturbed visual representation of space.

These results are consistent with prior findings that patients with bilateral parietal lesions leading to optic ataxia may be unable to reach to points in extrapersonal space under visual guidance, but may be able to reach to parts of their body with closed eyes. The present study suggests that the difficulty faced by RM, and perhaps other such patients is not a problem with reaching to extrapersonal space, compared to reaching to locations in body-defined space. Instead, they suggest that the difficulty faced by patients with optic ataxia is due to a severely disrupted visual representation of space that captures and degrades their otherwise good ability to reach. Thus visually guided action, supported by the parietal lobe [6] is severely compromised, whereas reaching per se may be relatively intact. In this respect, this patient appears similar to patients reported by Jackson and Hussain [10] with lesions to the supplementary motor cortex. Similarly, it has been suggested [11] that mis-reaching in neglect may be due to a disturbed visual representation of space. According to this study, patients with neglect may have intact both the representation of space and the ability to reach, but reaching actions may be distorted due to a disrupted visual representation that ‘captures’ hand action.
It has recently been suggested that some patients with optic ataxia may show a reduced deficit when they are gazing directly at the target [5]. This suggests that the parietal damage in these patients removes the ability to compute a viewer-based or scene-based representation of space [1], based on the combination of retinotopic information with eye-movement data. When the patient gazes directly at a target, it could be argued that retinotopic position alone could be used to guide the reaching action, thus mitigating the deficit. Furthermore, if the deficit faced by patients with optic ataxia was a difficulty in computing a viewer-based representation of space, then object-based spatial representations should be intact. Such a dissociation between, on one hand, disturbed reaching and, on the other hand, intact object grasp metrics and inter-object distance appreciation has been observed in patients with optic ataxia [16].

Our results can also provide one explanation of the ‘paradoxical’ improvement that has recently been reported [15] in a case of optic ataxia. These authors showed that reaching to remembered location was superior to reaching to a visual location. Our results suggest that the improvement in this case occurs simply because the visual input is not present in the ‘memory’ condition to misguide the reaching. It might be questioned as to how a low-error memory of the space could be constructed from a highly errorful visual input. If the errors are essentially random (as we found in the present study), then the superposition of multiple visual ‘snapshots’ of the scene would be averaged in memory to a representation with low spatial error.

Our results suggest that the deficits in visually-guided reaching seen in RM are not primarily caused by impairment to the control of reaching. Nor do they represent an abnormal sensitivity to visual distraction. In contrast they may be due to the disruptive effects of a distorted scene- or viewer-based visual representation that visually ‘captures’ and thus disturbs the reaching actions.

The question remains as to how typical RM might be as a patient with optic ataxia. In many cases described in the literature, including Balint’s classic case [2,3,9,16] optic ataxia appears largely confined to one hand. In such cases it is not possible to suggest that the deficit is truly visual in nature. Instead the disruption might be expected to be either in terms of a damaged connection between visuospatial representation and motoric representations, or damage to a hand-specific representation of space. Furthermore, patients in some studies show greater ability to make spatial descriptions, than to make spatial actions [16] in distinct contrast to the present study. These differences suggest that optic ataxia may best be considered a syndrome, in which different disruptions may lead to similar overall deficits. The present study suggests an approach whereby visual and motoric deficits can be dissociated.

Acknowledgements

Gordon C. Baylis was supported by grant from the National Science Foundation, SBR 16555-96. We thank RM for his good natured participation in this study.

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