An allocentric rather than perceptual deficit in patient DF

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The perception/action model states that vision for perception and action is processed in separate pathways. This model was inspired by observations in patient DF who seemed unable to use vision for perceptual tasks while retaining “normal” visuomotor capacity. I found that DF’s performance is preserved in perceptual and visuomotor tasks when the required spatial information is hand-centred and impaired when the information is object-centred.

In 1992 a seminal paper proposed a new model about the division of labour in the human visual pathway[1]. It was argued that the well-known anatomical segregation between a ventral and dorsal stream[2] corresponds to a functional specialization of vision for perception versus action. This model was inspired by the finding that DF, a patient with bilateral damage to the ventral stream, failed in perceptual tasks but not in visuomotor tasks[3]. Although some of the evidence for the model has been criticized (e.g. the evidence from visual illusions[4-6], and the evidence from optic ataxia[7]), the perception/action dissociation found in DF is still widely accepted as convincing evidence for the model[8]. Here I have examined the possibility that what has been described as a perception/action dissociation in DF may in reality be a dissociation between different modes of visuospatial processing, namely object-based spatial metrics (*allocentric mode*) versus observer-based metrics (*egocentric mode*). Normally the behavioural task and the spatial mode are confounded so that perceptual tasks use allocentric information, and visuomotor tasks use egocentric information.

In this study I decoupled the behavioural task and the spatial mode and asked DF (for details on DF, see[9]) and 10 healthy age-matched women to perform both a perceptual and a visuomotor task using either allocentric or egocentric information (**Fig. 1a** and **Supplementary Note**). All visual stimuli were computer-generated, projected onto a mirror covering the subject's hand and appeared to be in the same plane as the subject's hand. In the perceptual, allocentric task two dots were presented at various distances to the left and right of a cross. Subjects judged which of the two dots was closer to the cross. In the egocentric version the tip of the subject's index finger indicated the reference position. During the trial subjects did not receive visual information about the position of their finger, but had to rely on proprioceptive information. Please note that DF's proprioceptive performance is in the normal range (**Supplementary Note**). Before the start of the trial a cursor indicating the current position of the index finger was presented, allowing the subject to guide the finger to the reference position. The same procedure was used in the visuomotor tasks to guide subjects' fingers to their start position. In the allocentric version of the visuomotor task a target point was presented at various distances from a cross. In addition a square indicating the start position was presented at a separate location. Subjects were instructed to point to an invisible target whose position relative to their own start position was identical to the relative position of the target dot with respect to the cross. In the egocentric version of the visuomotor task, a target point was presented at a given horizontal distance from the start position, subjects had to move their finger from the start position to the target position. The movements were recorded with a Phantom Haptic Interface. To quantify the performance in the perceptual task the minimal difference between distances to obtain 80% correct answers was determined (i.e. 80% threshold). To allow a direct comparison between perceptual and visuomotor performance the distribution of the movement amplitudes in the visuomotor tasks was transformed into 80%-distance-discrimination threshold values. For all statistical comparisons a t-test which was specifically developed for single-case studies was employed[10].

DF's performance in the allocentric perceptual task was significantly impaired (t_9=22.92; *P*<0.0001), whereas her egocentric, visuomotor performance was normal (t_9=0.52; *P*<0.284). This confirms earlier demonstrations of "perception/action" dissociations in DF. However, the results from the other two conditions did not fit the pattern of a perception/action dissociation. DF's perceptual performance was normal in the egocentric condition (t_9=1.68; *P*<0.063), whereas her visuomotor performance was abnormal in the allocentric condition (t_9=9.94; *P*<0.0001; **Figs.1b,c** and **Fig. 2**).

These results suggest that the crucial factor determining DF's performance is not the task (i.e. perceptual versus visuomotor) but the spatial mode (i.e. allocentric versus egocentric). Differences in the required spatial mode can also explain the "perception/action" dissociations found for object size. In this case size estimation (perception) is compared with grasping (visuomotor), and again DF is better in the visuomotor task[9]. However, for size estimation the relative size is used, whereas conventional grasping uses the object's absolute size. In fact as soon as the relative size of an object's dimensions is made relevant for the grasping, DF's performance becomes impaired[11]. Thus, characterizing DF's deficit as an impairment of object-centred or scene-based representation of position and size can account for the "perception/action" dissociations and in addition correctly predicts that DF's perceptual performance is preserved in an egocentric condition.

However, there might be an alternative explanation for DF's improved performance in the egocentric perceptual task. Let's assume that DF suffers from simultanagnosia. In this case DF would find it difficult to compare two or more visual objects, but would find it easier to compare a visual with a non-visual object. This could explain why DF's performance in the egocentric condition, where a non-visual signal indicates the reference position, is better than in the allocentric condition with a visual reference signal. However, in a test for simultanagnosia using the set of stimuli also used in the allocentric perceptual task, DF showed no sign of simultanagnosia (**Supplementary Note)**. It is also important to note that the simultanagnosia interpretation would not defuse the challenge posed by our findings to the perception/action model. If we accept that the simultanagnosia interpretation explains the dissociation between the "allocentric" and "egocentric" condition in the perceptual tasks, we will also have to accept that it can explain the similar dissociation found in the visuomotor tasks. This would bring us to a conclusion which is similar to ours, namely that the crucial factor in determining DF's behaviour is how the target information is presented and not which behavioural response is required.

The finding of DF's normal performance in the egocentric perceptual task is also surprising in light of the recently presented argument that the perceptual representation of visual objects can only be achieved within an allocentric framework[12]. The present results show that egocentric spatial positions can be perceptually represented even when allocentric coding is impaired, and therefore suggest that this argument[12] does not extend beyond objects to positions.

The present findings challenge the conventional interpretation of "perception/action" dissociations in DF, and thereby undermine an important, but not the only source of support for the perception/action model. Optic ataxia has been presented as another, complementary example of a perception/action dissociation with action impaired and perception preserved[1,13]. However, this interpretation of optic ataxia was disputed[7]. It was argued that a more appropriate characterization of optic ataxia should emphasize the distinction between central and peripheral vision rather than the distinction between perception and action[7]. Other studies have shown that optic ataxia affects only specific aspects of visuomotor behaviour[14] and egocentric coding[15]. It thus appears that neither the perception/action nor the allocentric/egocentric distinction can provide a satisfactory account of this complex disorder.

In conclusion, DF's performance was impaired in allocentric and preserved in egocentric conditions for both perceptual and motor tasks. These findings are inconsistent with a perception/action explanation of DF's behaviour, and therefore undermine one of the main pillars of the perception/action model.

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Captions

Figure 1. Illustration of the four tasks and group results. **(a)** This panel illustrates the experimental tasks. Please note that the hand is presented for ease of illustration but was invisible during the trial. **(b)** and **(c)** present the distance-discrimination thresholds for the perceptual and visuomotor task, respectively. Open circles represent the values for control subjects, the black triangles show DF's values; the horizontal lines represents the group average in the respective conditions. The results show that DF's performance is consistently outside the normal range in the allocentric version, and within the normal range in the egocentric version of both tasks.

Figure 2. Illustration of individual results. (**a), (b)**. Performance in the perceptual task for a control subject (a) and patient DF (b). The graphs show the discrimination accuracy (i.e. percentage of correct responses) as a function of the difference in the distances between the two dots and the reference line. Empty circles (dashed line) represent the results from the allocentric condition. Filled circles (continuous line) represent the results from the egocentric condition. The continuous horizontal line represents the threshold level (80% correct judgements). **(c), (d)**. Performance in the visuomotor task for a control subject (c) and patient DF (d). The graphs present the response amplitude (mean/s.d.) of the pointing movement as a function of the target distance. The same symbols are used as in (a) and (b).

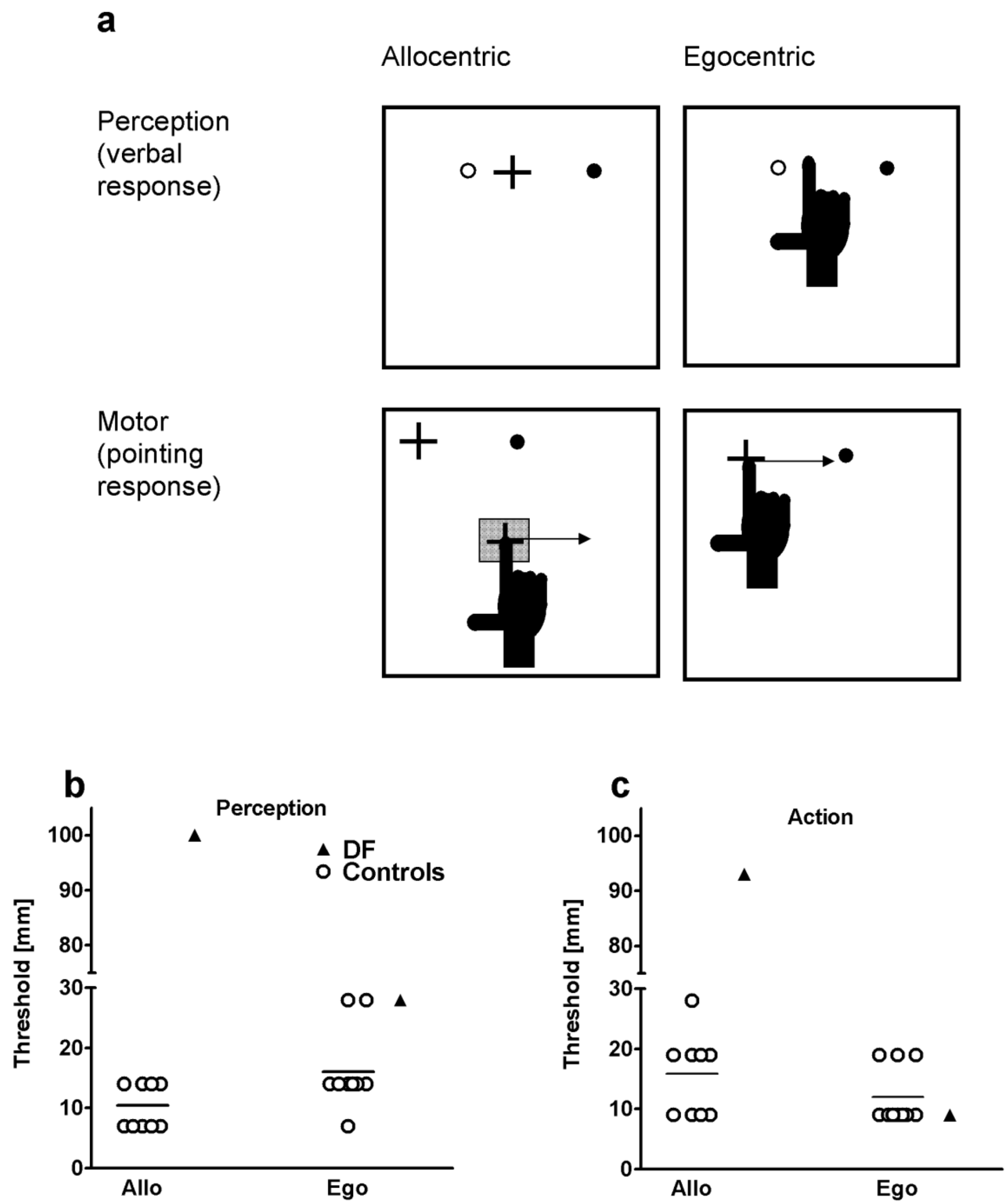
a
Allocentric
Egocentric
Perception
(verbal
response)
Motor
(pointing
response)
b
Perception
DF
Controls
Threshold [mm]
0
10
20
30
80
90
100
Allo
Ego
c
Action
Threshold [mm]
0
10
20
30
80
90
100
Allo
Ego

Figure 1

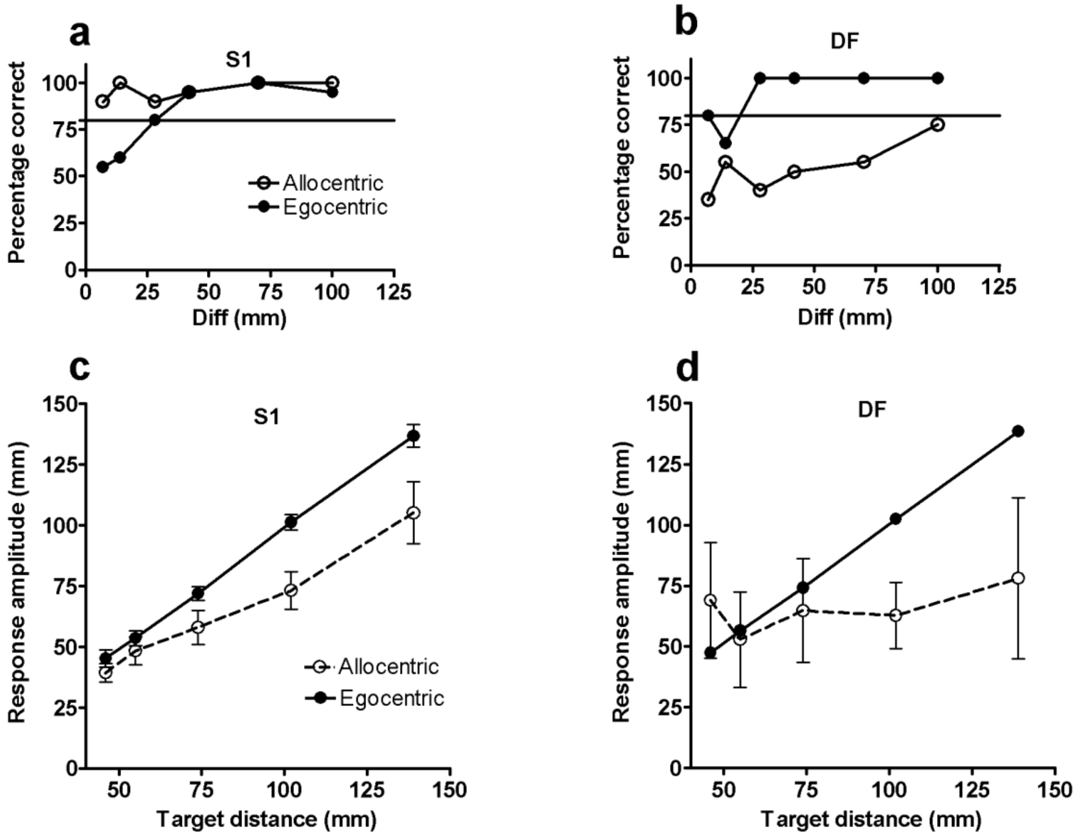
a
S1
Percentage correct
Allocentric
Egocentric
Diff (mm)
b
DF
Percentage correct
Diff (mm)
c
S1
Response amplitude (mm)
Allocentric
Egocentric
Target distance (mm)
d
DF
Response amplitude (mm)
Target distance (mm)

Figure 2