

# Spatial reference frames and hierarchical object representations: Evidence from drawing in hemispatial neglect

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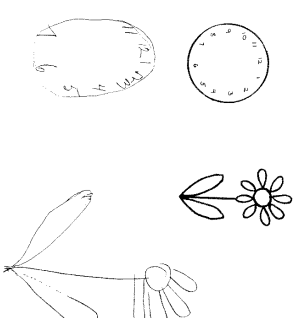
Poster presented at the 37th Meeting of the Psychonomic Society, Chicago, IL, October 1996.



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## Background

Patients with *hemispatial neglect*, an attentional deficit typically caused by brain damage to the right parietal lobe, ignore information on the left side, despite intact intellectual, motor and sensory function. The deficit manifests in a variety of tasks, including drawing or copying an object or scene, in which parts on the left side are often omitted.



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## Abstract

When drawing, patients with right parietal lesions typically omit details on the left side of figures. We present empirical evidence for the sensitivity of such drawing to object orientation and structure, and provide a computational account in terms of the interaction among multiple reference frames and hierarchical object representations. Neglect is successfully modeled as a monotonic drop-off in attention from right to left that affects performance in both viewer-centered and (hierarchically defined) object-centered reference frames.

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## With respect to what frame of reference is “left” defined?

We focus on two possibilities:

1. **Viewer-centered** or egocentric: Frame defined relative to the retina, head or body trunk of the viewer.
2. **Object-centered** or allocentric: Frame defined relative to the canonical upright of an object or environment.

Under standard viewing conditions these frames are aligned and so their relative effects are confounded. They have been decoupled experimentally primarily in two ways:

### Rotating the object or viewer

When neglect patients view rotated objects, or are placed on their side and view upright objects, both viewer-centered and object-centered frames simultaneously influence performance in perceptual tasks. That is, object features are less likely to be detected when the fall to the left of the midline of either the viewer or the object (Behrmann & Moscovitch, 1994; Driver & Halligan, 1991; Young, Hellawell, & Welch, 1991)

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### Using hierarchically structured objects

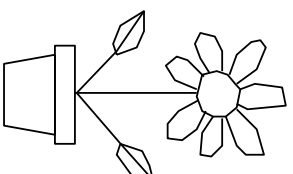
During drawing tasks, an object-centered frame is assigned sequentially to each object in a scene, and to the subparts of a single complex object. Such frames are not typically aligned with the viewer-centered midline, allowing object- and viewer-centered effects to be decoupled. In particular, neglect patients may succeed at copying the right sides of objects positioned to the left of other objects whose left sides are omitted (Gainotti, Messerli, & Tissot, 1972; Marshall & Halligan, 1993) or they may fail to copy an entire part on the left of an object (e.g., the left wheel of a bicycle) but may fail to copy only the left side of the same part presented as an isolated object (e.g., the left spokes of a wheel; Driver & Halligan, 1991).

In the current work, we employ both of these manipulations with neglect patients performing a copying task, and develop a computational account of how the relative contributions of viewer-centered and object-centered frames interact with object structure to give rise to the observed neglect behavior.

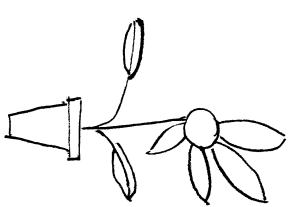
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### Experiment 1: Results (Patient JM)

Original



Copy



Standard neglect pattern: omission of leftmost petals.

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### Experiment 1: Copying misoriented objects

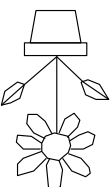
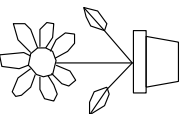
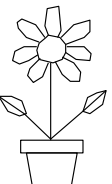
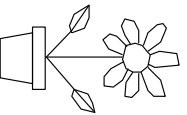
As shown above, when copying a daisy, neglect patients typically omit the leftmost petals (and often the leaf). How is the pattern of performance influenced when the daisy is misoriented? (Note that a daisy has a clear, canonical upright.)

#### Patients

- **JM:** 52 year-old right-handed male, suffered right parietal CVA (Jun 1992) with some anterior extension in frontal region. Moderate left neglect (39/40 on Sunnybrook Bedside Neglect battery) with resolved hemianopia.
- **GS:** 64 year-old right-handed male, suffered right parietal CVA (Jan 96) with some edema. Moderate left neglect (41/100 on battery) with no hemianopia.

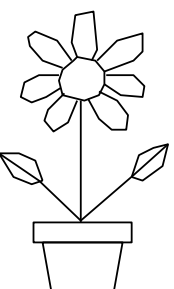
#### Method

- Picture of an individual daisy presented for copying centered on the page twice in each of four orientations: up, left, down, right.

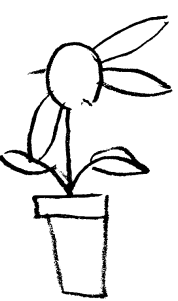


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Original



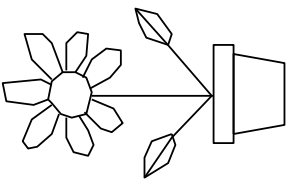
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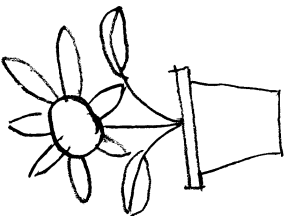
Combination of object-centered effects: Petals both to the object-centered left (downward on the page) and viewer-centered left (left of the page) are omitted. (n.b. Petal to the upper right on the page was drawn and then erased.)

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Original



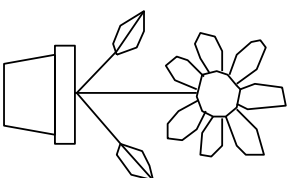
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Very little neglect; perhaps mild object-centered effect: Petals on the right of the page (left of the daisy) are smaller.

### Experiment 1: Results (Patient GS)

Original

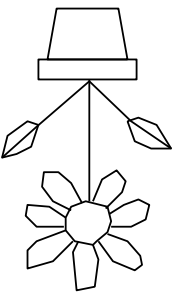


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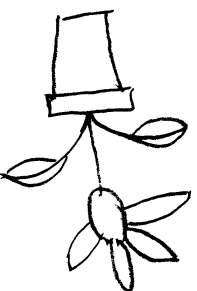


Strong neglect, including contrapositioning of right branch and leaf (see also Halligan, Marshall, & Wade, 1992).

Original

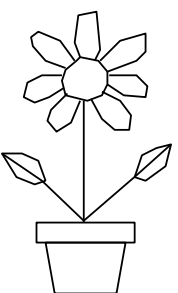


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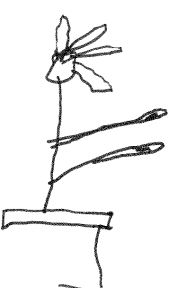


Circle was drawn first, then petals. Viewer-centered effects predominate initially (petals omitted to the left of the circle) because the circle lacks a clear object-centered orientation with respect to the daisy.

Original

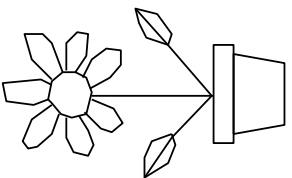


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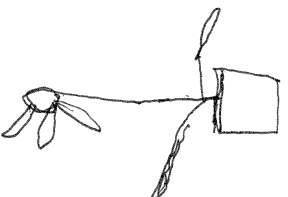


Again, strong object-centered neglect with contrapositioning. Note that neglect is sufficiently strong to override grouping of segments forming the base.

Original



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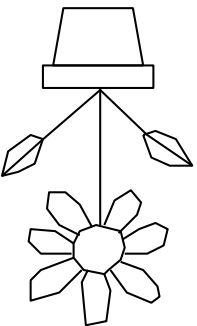


Copy of inverted daisy shows strong *viewer-centered* neglect: Petals to the left of the page are omitted.

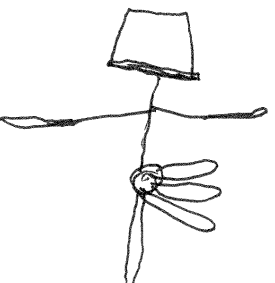
## Experiment 1: Conclusions

- Neglect patients show clear evidence of the simultaneous combination of viewer-centered and object-centered effects when copying upright and misoriented daisies.
- One patient (JM) showed a fairly consistent pattern of performance reflecting a particular balance of object- and viewer-centered effects.
- The other patient (GS) exhibited far more variable performance, showing strong object-centered effects in some conditions and strong viewer-centered effects in others.

Original



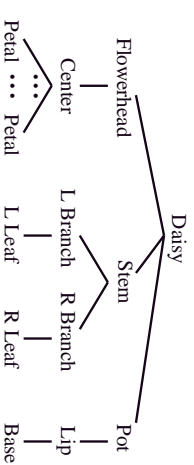
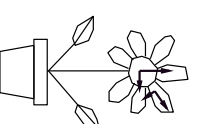
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Similar to JM in that circle was drawn initially and the petals to the viewer-centered left of it were omitted.

## General account

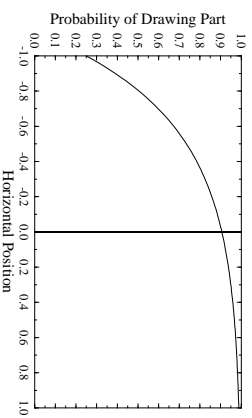
- Object representations are organized hierarchically, such that each part (“child”) of an object (“parent”) can also be considered an object in its own right (with its own object-centered frame; Marr, 1982). The object-centered frame of a child—its position and orientation—is defined relative to that of its parent.



- Drawing an object from memory, or copying a figure using object knowledge, involves traversing this hierarchical representation.
- During the traversal, the likelihood of drawing a part in neglect depends simultaneously on its viewer-centered position (assumed to remain fixed) and on its object-centered position (defined relative to its parent) (see Humphreys & Riddoch, 1995, for a similar perspective)

## Computational algorithm

- Parts in the hierarchy for an object are traversed in “depth-first” order: All the subparts of one part are considered before moving on to the next part at that level (“sibling”) (see Ho, Behrmann, & Plaut, 1995, for some empirical support for this claim)
- The probability of drawing a part is a weighted average of the probabilities of drawing it in the viewer-centered frame (defined by the page and fixed) and in the object-centered frame (defined by its parent), each of which is a monotonic function of its horizontal position within the frame:

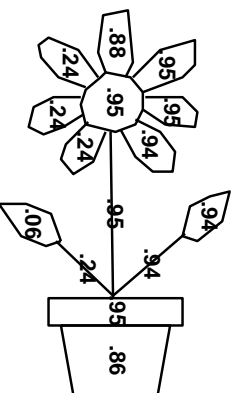
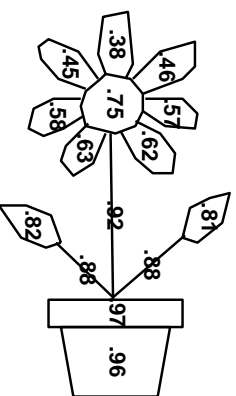


- The resulting probability for a child is multiplied by the probability of its parent (if a parent is not drawn, none of its children are drawn).

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## Simulation 1: Copying misoriented daisies

Probabilities of drawing each part of a left-facing daisy when subject to neglect that is either entirely viewer-centered or object-centered.

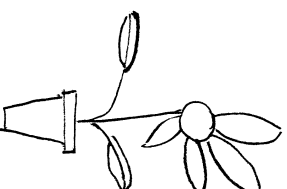


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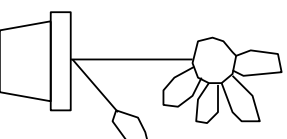
## Simulation 1: Results (Modeling JM)

- Neglect is 60% viewer-centered, 40% object-centered
- Probability threshold of 0.57 for drawing parts

Patient's Copy



Model



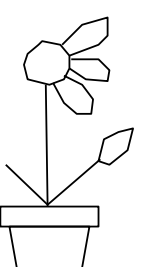
Model over-neglects left branch but otherwise matches well.

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Patient's Copy



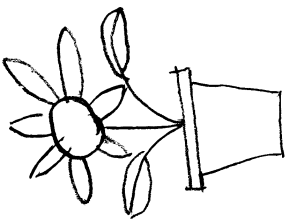
Model



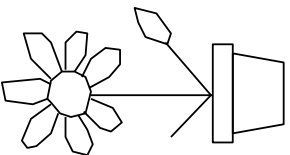
Except for omitting left leaf, model provides a nice match to the mixture of object- and viewer-centered effects shown by JM.

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### Patient's Copy



### Model

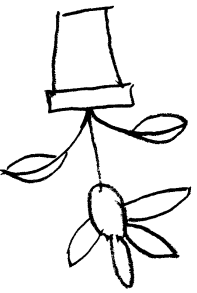


Model provides a clear account of the lack of neglect in copying an inverted daisy: Viewer- and object-centered effects are in opposition (parts that are relatively neglected in one are relatively preserved in the other); Neither alone is sufficient to manifest overtly.

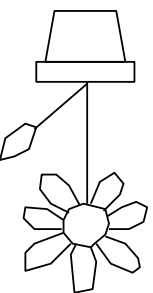
## Simulation 1: Conclusions

- The model provides a reasonable account of the mixture of viewer- and object-centered effects in the copying performance of patient JM.
- A particularly interesting finding is that the relative contributions of viewer- and object-centered frames may balance when copying an inverted object, giving rise to little if any overt neglect.
- The performance of patient GS was not modeled explicitly but might correspond to a condition in which, at any given time, copying is governed by either a viewer- or object-centered frame (rather than a mixture). Contrapositioning might be incorporated by including an assumption that, at least in symmetric objects, the representation of horizontal position is not code handedness very robustly.

### Patient's Copy



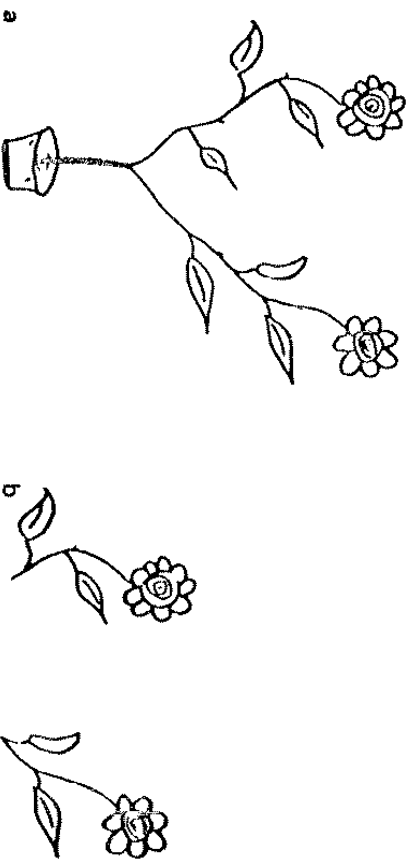
### Model



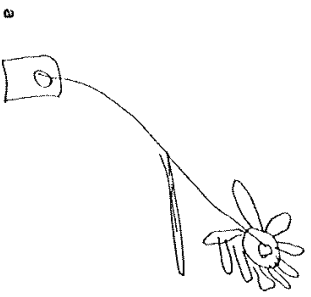
Circle in the model was assigned a canonical upright (aligned with that of the daisy) and so the model in its current form does not account for the (temporary) assignment of a viewer-centered frame to objects with no intrinsic orientation.

## Experiment 2: Hierarchically complex objects

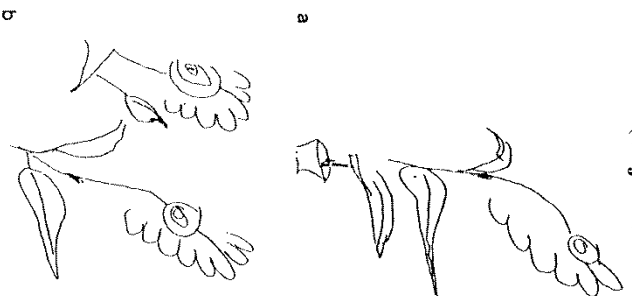
Viewer- and object-centered effects can be decoupled within complex objects with many levels of object-centered frames. A single isolated daisy has a fairly simple hierarchy; Marshall and Halligan (1993) investigated neglect copying of a more hierarchical version—a *two-headed daisy*—compared with copying the same two component daisies as separate objects.



Patient P1 (Viewer-Centered)

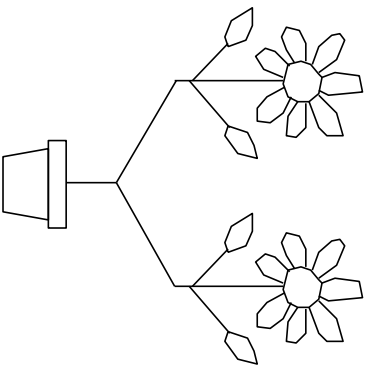


Patient P2 (Object-Centered)

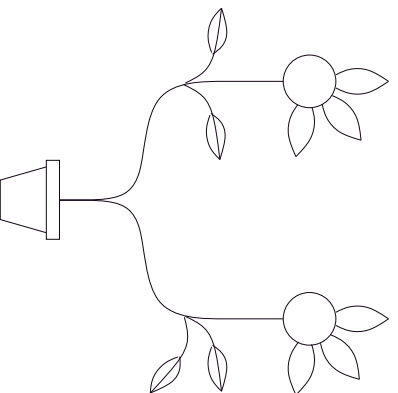


### Experiment 2: Results (Patient GS)

Model

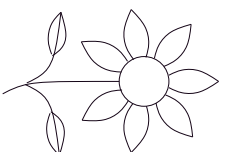


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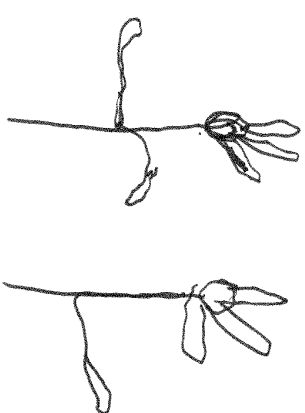


Depiction—actual drawing unavailable

Model



Copy



### Experiment 2: Conclusions

- Neglect patients vary considerably in the degree to which they show viewer-centered vs. object-centered effects in copying complex, hierarchically structured objects.
- Patient GS shows predominantly object-centered effects.

## Simulation 2: Copying two-headed daisy

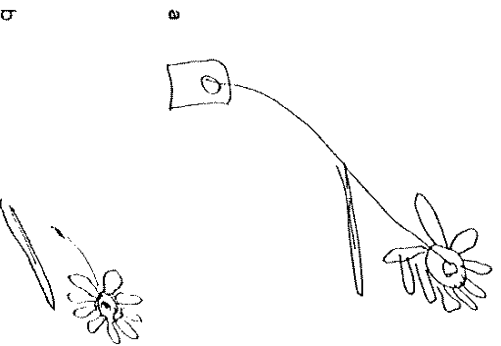
- Object hierarchy for two-headed daisy is simple combination of two single daisy hierarchies.
- Computational algorithm for neglect drawing applied exactly as in Simulation 1.

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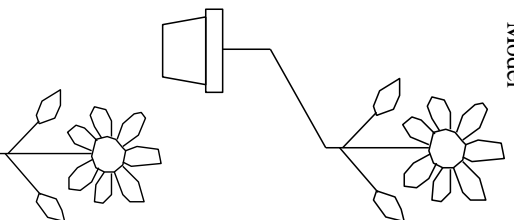
## Simulation 2: Marshall & Halligan (1993) patients

100% Viewer-centered neglect

Patient P1



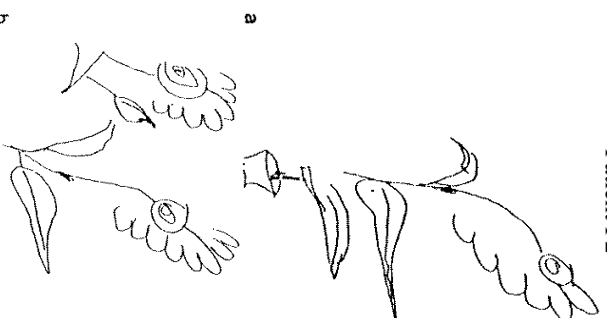
Model



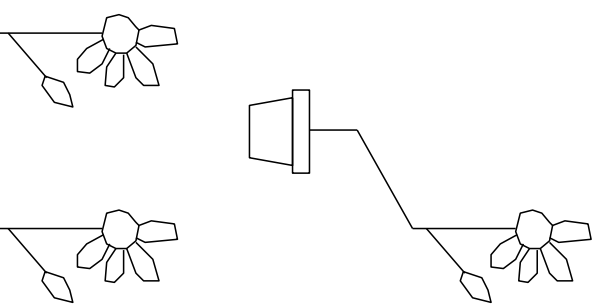
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75% Object-centered neglect; 25% Viewer-centered neglect

Patient P2



Model

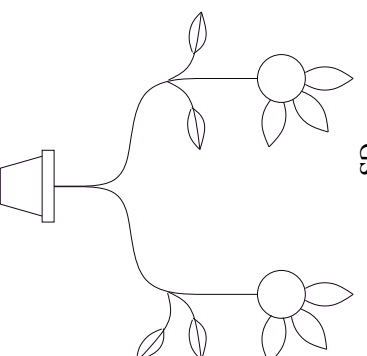


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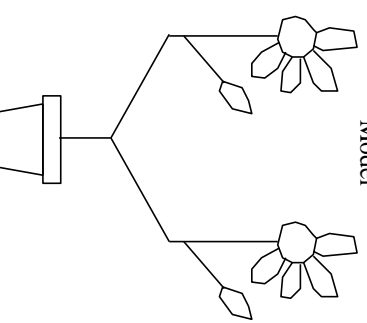
## Simulation 2: Results (GS)

100% Object-centered neglect

GS



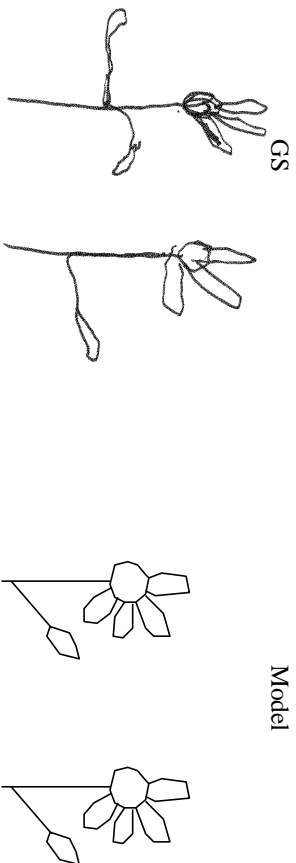
Model



Depiction—Actual drawing unavailable

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## Summary

- Patients with *hemispatial neglect* due to right parietal damage ignore information on the left side of space in a variety of tasks, including drawing or copying an object or scene, in which parts on the left side are often omitted (e.g., the leftmost petals of a daisy).
- The attentional impairment in neglect manifests in both viewer-centered and object-centered reference frames. Moreover, the object-centered effects depend on the hierarchical structure of objects. In upright objects, however, the relative effects of viewer-centered and object-centered frames are confounded.
- In the current work we deconfounded these frames in a copying task either by rotating the object to be copied or by using a hierarchically complex object (a two-headed daisy; Marshall & Halligan, 1993).
- Neglect copying performance revealed interesting interactions of spatial reference frame and hierarchical object structure, with considerable differences across patients.
- We also provide a computational account of how the relative contributions of viewer-centered and object-centered frames interact with object structure to give rise to the observed neglect behavior.

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## Simulation 2: Conclusions

- The model provides a good match to very different patterns of neglect performance in copying the two-headed daisy and the two single daisies, ranging from exclusively viewer-centered effects (Patient P1) through a mixture of viewer- and object-centered effects (Patient P2) to exclusively object-centered effects (Patient GS).
- In each case (and in the model), there are interesting interactions between viewer- and/or object-centered reference frames and the hierarchical structure of objects.

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