

Spatial direction comprehension in images, arrows, and words in two patients with posterior cortical atrophy

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### Abstract

To successfully move through the world, the brain constructs spatial representations that situate the body within the environment. Communicating spatial directions poses specific challenges to this process, in part because the format through which the information is communicated must be interpreted to match the visual scene the navigator is viewing while traversing that space. For example, if a navigator needs to turn left to reach a goal, the information may be presented in the form of words (“turn left”), schemas (arrows pointing left), or images of the specific left turn. Previous research has suggested unique representations exist for spatial directions within and across modalities. Behavioral data reveal, for instance, that interpreting images seems to require spatial information, whereas words or schemas can be processed using a visual-matching strategy. In the current pre-registered study, we tested two patients with posterior cortical atrophy, who did not have spatial neglect, to determine whether they had general impairments interpreting spatial directions across formats, or specific impairments in particular formats. Our results are consistent with the specific impairment prediction, supporting the idea that the interpreting spatial directions in images requires action-relevant spatial processing. We conducted single-case analyses for the patients we tested in comparison to a group of non-clinically diagnosed older adults. Of the two patients, one showed a classical dissociation between a color control task and spatial directions across all modalities. This patient also showed a classical dissociation between images (most impaired) and schemas, and between schemas and words (least impaired). Our findings lend support for a hypothesized hub in the spatial navigation network, which converts format-specific information into actionable spatial directions, and has implications for designing the built environment to optimize for spatial behavior.

Keywords (6 maximum): spatial cognition, spatial navigation, posterior cortical atrophy, spatial communication

Highlights

3-5 bullets; 85 characters per bullet including spaces

- Posterior cortical atrophy (PCA) is a neurodegenerative condition affecting the parietal lobes
- We tested two PCA patients on spatial directions in images, words, and schemas
- One patient was unimpaired. The other was impaired on images, not words or schemas
- Results suggest distinct neural processing of the different formats
- Giving PCA patients spatial directions in words or schemas may improve navigation

Getting lost, whether in the woods or in a poorly laid out hospital, can be a profoundly frightening and dangerous experience. Although spatial navigation can be cognitively demanding, informative and well-placed signs can ease the cognitive burden of knowing where one is and potentially prevent people from getting lost. Indeed, people use a variety of navigational tools – blazes on trees, compasses, maps, arrows, and verbal directions – to provide accessible and salient spatial directions. Despite the use of these tools, becoming lost is a particular challenge to the health and safety of older adults, particularly those with dementia. But what are effective ways to support spatial navigation behavior?

One approach to this question is to assess spatial direction comprehension within various formats. For example, spatial directions can be presented in words (“turn left”) in visual scenes (an image, a photograph, or a real-world scene containing distinct paths) and in what we have called schemas (like arrows pointing in particular directions). Visual schemas are a general class of a representational format in which the specific details of a concept are removed, but the depiction resembles how the concept appears in the world (Amorapanth et al., 2012; Kranjec et al., 2013; Quandt et al., 2017). Research on actions (Quandt et al., 2017) and prepositions (Amorapanth et al., 2010) reveal distinct behavioral and neural processing of schemas compared to words and images.

Recent work on spatial direction comprehension has revealed that schemas and words are processed more quickly and accurately compared to images (Weisberg et al., 2018). fMRI data has also revealed that the intraparietal sulcus (IPS) is key to representing spatial directions in real and virtual environments, as well as across formats (Schindler & Bartels, 2013; Weisberg et al., 2018). Whereas formats were processed separately by distinct regions of the brain (e.g., visual scenes activated the visual scene network; words activated the visual word-form area; and

schemas activated lateral occipital complex), none of these regions contained information about spatial directions. Rather, multi-voxel pattern analysis revealed that the IPS distinguished spatial directions within images and across all three formats. These data suggest that the IPS plays a key role in transforming visual information into a usable spatial context. Although research has implicated the parietal lobes in spatial processing, no studies have determined whether alternate formats of information (e.g., from schemas or words) require the involvement of the parietal lobes. This gap has important theoretical implications for the necessity of parietal lobe function in spatial direction comprehension, as well as practical implications on how to provide spatial information to impaired navigators.

Patients with posterior cortical atrophy (PCA) may provide insight into the involvement of the parietal lobes in spatial direction comprehension. A non-amnesic variant of Alzheimer's disease, PCA results in loss of cortical tissue primarily in the parietal lobes, but also parts of the posterior temporal and occipital lobes (Crutch et al., 2017). Depending on the severity and location of the atrophy, patients produce a range of behavioral deficits, including visuospatial difficulties, 3D shape interpretation, (Gillebert et al., 2015), visual agnosias, and visual neglect. Given the involvement of the parietal lobes in processing spatial directions across formats, these patients are good candidates to test the hypothesis that the parietal lobe is involved in spatial direction comprehension.

In the present pre-registered study, we tested two PCA patients on their ability to interpret spatial directions within each of three formats: words, images, and schemas. We compared these patients to healthy older adults. Given the ambiguity in the fMRI findings on the involvement of the parietal lobes in spatial direction comprehension, we had two competing predictions about how PCA patients could show spatial deficits. On the one hand, since IPS may

code for spatial information across all three formats, PCA patients might be impaired on all formats equally. On the other hand, since behavioral data suggested that words and schemas may elide the spatial processing required by the images, PCA patients may show disproportionate impairments on images, and relatively spared performance on the other formats.

## **Materials and Methods**

### **Participants**

We recruited two patients who had been diagnosed by a licensed clinician with PCA (Figure 1). PCA diagnosis required visual perceptual-spatial deficits (e.g., deficits in object and spatial perception, visual neglect, simultagnosia, and/or oculomotor apraxia) and relative preservation of other cognitive abilities (e.g., memory, executive, and language function; Crutch et al., 2017). Five healthy age and education-matched control participants were recruited from a database maintained by the Penn Memory Center. Relevant patient and control demographic and neuropsychological testing are reported in Table 1. For patients, neuropsychological and cognitive testing was performed between 4-6 months after (PCA\_1) or 3 weeks before (PCA\_2) testing for the current experiment. For control participants, neuropsychological testing was performed within twelve months. Although both patients appeared to have mild unilateral spatial neglect as measured by the line bisection test, their deficit was not greater than two of the control subjects who we also tested.

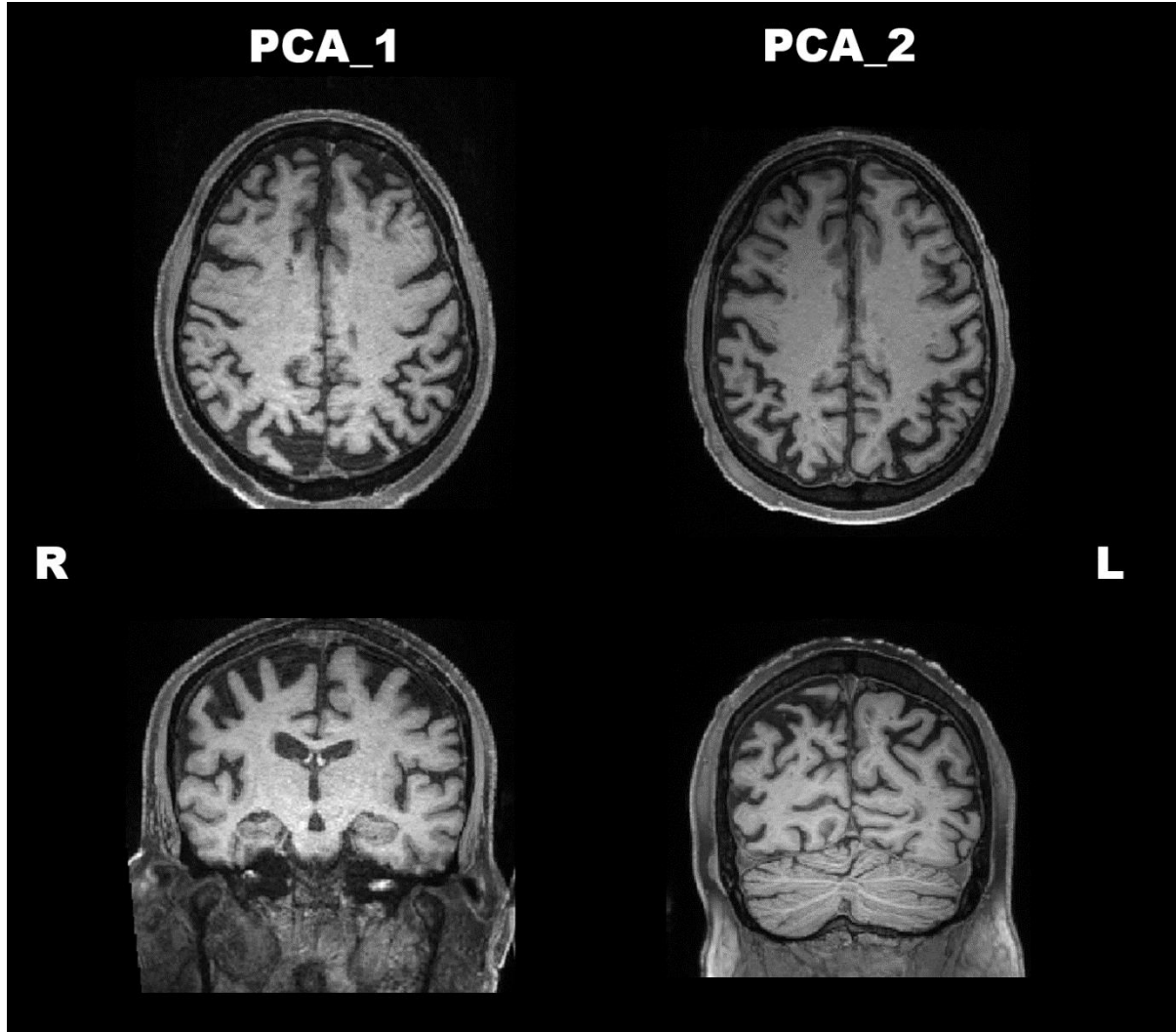


Figure 1. Structural (T1-weighted) MRI images of the two patients recruited in the behavioral experiment.



*Table 1. Demographics and Neuropsychological Data*

Participant	Age	Gender	Education	MOCA	MMSE	JOLO	Line Bisection	CS:IR (V)	MINT
PCA_1	70	M	16	21	23	5	-12.1	22	31
PCA_2	59	M	12	18	22	3	-8.3	12	29
Control_1	63	M	12	30	30		-3.9	25	32
Control_2	71	F	18	27	29		-15.1	17	31
Control_3	68	M	12	26	29		1.9	30	32
Control_4	91	F	20	29	30		-11.6	18	31
Control_5	75	M	16	26	29		4.7	15	32

Note: Demographics and neuropsychological for the two posterior cortical atrophy patients and five aged controls. Line bisection was collected in the same session as the main experiment and is reported in millimeters away from center (negative indicates bias to the patient's left). A single dissociation test (Crawford & Garthwaite, 2007) revealed no statistically significant deficit for either PCA patient compared to controls. The Judgment of Line Orientation test (JOLO) was not collected in controls. Education is in years. PCA (Posterior Cortical Atrophy); MOCA (Montreal Cognitive Assessment); MMSE (Mini-Mental State Exam); JOLO (Judgment of Line Orientation); CS:IR(V) (Craft Story: Immediate Response; verbatim coding); MINT (Multilingual Naming Test).

### **Behavioral Measures**

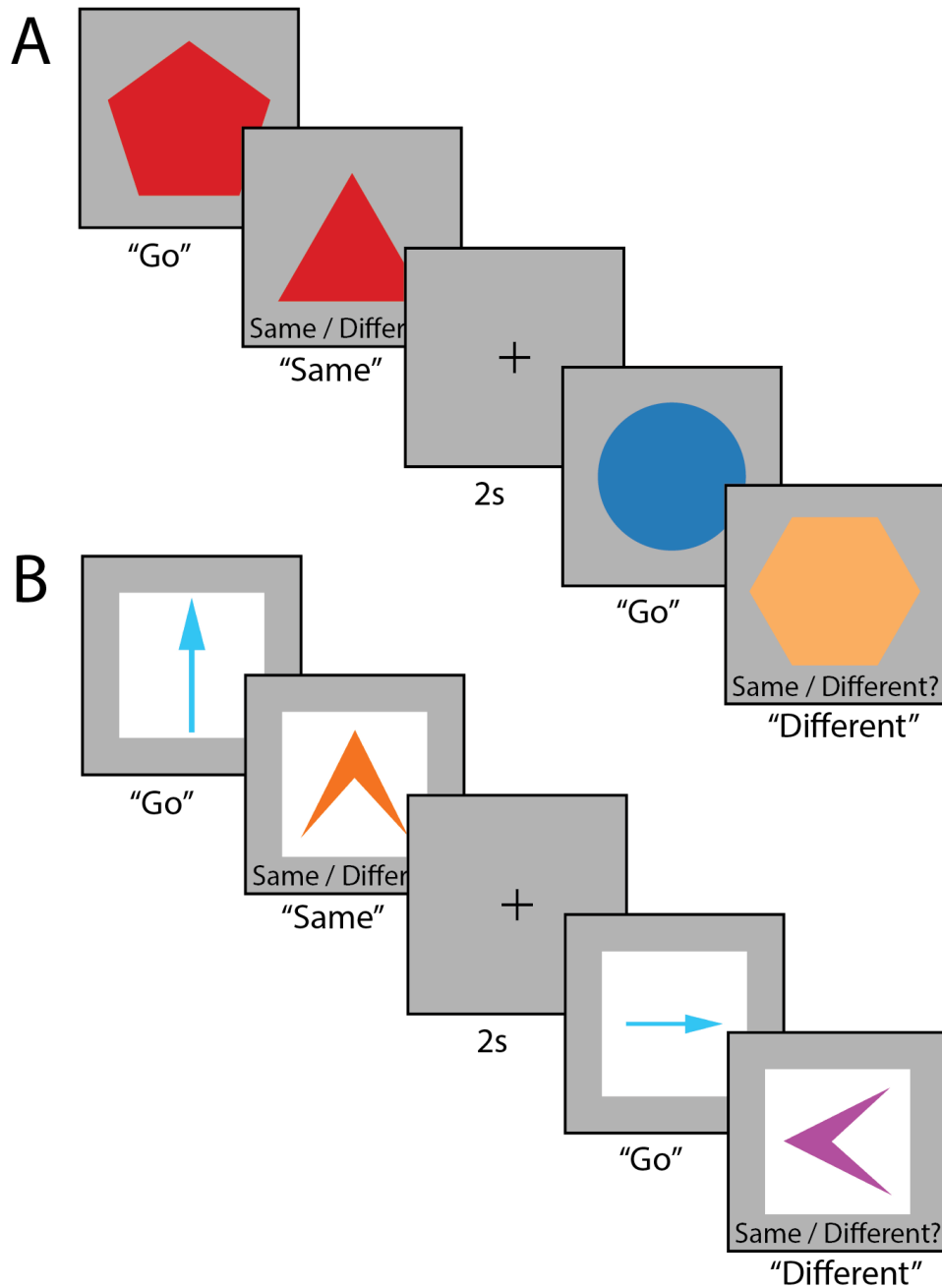
**Demographics.** We asked participants to report their biological sex, gender, ethnicity, age, education level, and handedness.

**Color match task.** We developed the color match task as a control task to ensure participants could process non-spatial visual information and could understand the task instructions. The color match task was presented in PsychoPy (Peirce, 2007). Red, orange, and blue color stimuli were generated in PsychoPy in the shape of either a circle, triangle, square, pentagon, or hexagon superimposed on a grey background. Shapes appeared one at a time in the center of the screen. Each trial consisted of a pair of shapes, presented sequentially. The participant was told to pay attention to the color of each shape and determine whether the pair consisted of shapes that were the same color or different colors. Before the task, participants received verbal instructions explaining the task, appearing on the laptop computer and read aloud

by the experimenter (SMW). The participant also viewed examples of shapes that were the same color or different colors. The participants was instructed that blue, red, and orange would be the only colors used. After the instructions, participants completed two sets of 12 practice trials, after which they had an opportunity to ask any questions about the task. Each block consisted of at least one same trial and at least one different trial. The practice trials were the same structure as the actual test.

The actual task structure was as follows (see Figure 2 for a diagrammatic depiction of the task structure). The first shape appeared on screen. Participant viewed the first shape, then, when they were ready, verbally instructed the experimenter to proceed to the second shape by saying “Go.” The experimenter then pressed a key to advance to the next shape. Under the second shape appeared the prompt: “SAME / DIFFERENT?” If the two shapes had the same color, the participant verbally responded “Same.” If the two shapes had different colors, the participant verbally responded “Different.” The experimenter recorded the response by pressing the assigned button on a 4-button response box. Participants were instructed to respond as accurately as they could. After each trial (one pair of shapes), a fixation cross appeared on the screen for 2s, then the next trial began with a new shape appearing on screen automatically.

Trials were presented in sequences of twenty after which the participant took a short break. 60 trials were presented total. Unique pseudorandom trial sequences were generated for each participant with the constraints that a) no color could appear more than 21 times as the first stimulus, b) no color could appear more than 21 times as the second stimulus, c) no color could appear four or more times in a row, d) a maximum of two same or two different trials could occur in a row. Same and different trials were otherwise randomly generated such that, on average, each participant received an equal number of same and different trials.



**Figure 2.** Structure of the color task and the spatial task. The task for both domains was the same. Participants always completed the color task first followed by the spatial task. Each pair of stimuli constitute one trial. On each trial, the participant was instructed to encode either the color (A) or spatial direction (B) of the first stimulus. When ready, the participant said "go" aloud. When the next stimulus appeared, the participant responded with the word "same" if the color (or spatial direction) of the second stimulus matched the first stimulus or the word "different" if the color (or spatial direction) did not match. After the experimenter pressed the button to input the

response, a fixation cross appeared for two seconds, followed by the first stimulus for the next trial.

**Spatial direction match task.** The spatial direction match task was also presented in PsychoPy (Peirce, 2007). Spatial direction stimuli were a subset of the stimuli as used in the behavioral study from (Weisberg et al., 2018), examples of which can be seen in Figure 3. Schemas and words were generated in Adobe Photoshop and varied in size (small, medium, large), color (orange, pink, blue, yellow), and style (chevrons and arrows for schemas; two different fonts for words). Schemas and words were superimposed over a square white background. Images were collected as screenshots of roads from Google Earth that turned either left or right, or went straight (ahead). Images were also subjected to a norming study in which independent raters reported which spatial direction was depicted in each so they matched across spatial directions (see Weisberg et al., 2018 for details). All stimuli were presented in the center of the screen on a grey background (which was behind the white background for schemas and words).

As with the color match task, participants received instruction and completed practice trials for each of the three formats (schemas, images, and words) used for the spatial direction task. After describing the task structure again, participants were shown two examples of each spatial direction for the three formats (in a fixed order: schemas, then words, then images; within format, spatial directions were also presented in a fixed order: right, then ahead, then left). After initially naming the three spatial directions (“right,” “left,” and “ahead”), to account for the possibility that the participant might not be able to view each spatial direction as distinct in each format, the experimenter guided the participant’s hand to trace the spatial direction for the images and schemas. For word examples, the experimenter guided the participant’s hand along

the bottom of the word (from left to right), but did not read the word nor indicate the spatial direction with the participant's hand.

Participants then completed two sets of 12 practice trials. Each set of twelve practice trials consisted of 3 format blocks (order of blocks was randomized within set and across participants). Each practice set consisted of 4 schema trials, 4 word trials, and 4 image trials. Each block consisted of at least one same trial and at least one different trial. Again, participants had the opportunity to ask questions about the task structure between practice sets and before the actual experiment. Stimuli used in examples and practice trials were not used for the main experiment.

The spatial direction match task was identical to the color match task in structure (see Figure 1B), with the following differences. 180 trials were administered total in 18 blocks of 10 trials each. Each set of 10 trials consisted of one format – either schemas (depicted in Figure 2B), words, or images. Each set of 3 blocks consisted of a randomly-ordered set of the three formats, with each possible ordering of formats occurring once per participant.

Unique pseudorandom trial sequences were generated for each format and for each participant with the constraints that a) no spatial direction could appear more than 125 times overall, b) no spatial direction could appear more than 21 times as the first stimulus within one format, c) no spatial direction could appear more than 21 times as the second stimulus within one format, d) no spatial direction could appear four times in a row, e) a maximum of two same or two different trials could occur in a row. Same and different trials were otherwise randomly generated such that, on average, each participant received an equal number of same and different trials.

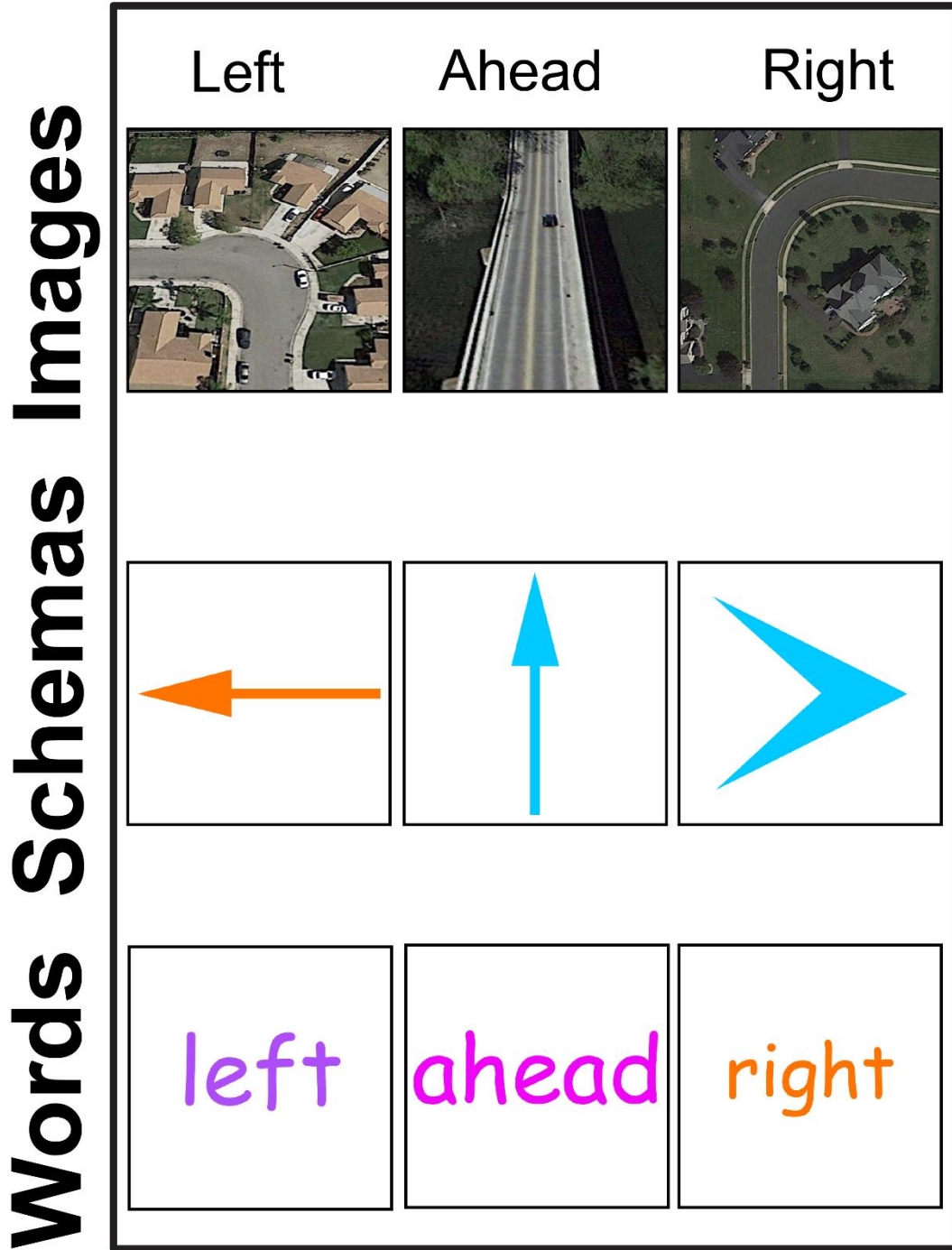


Figure 3. Example images of the three spatial directions and formats.

## Experimental Procedure

Participants were tested individually by the one of the co-authors (SMW) in a private testing room. Participants first provided and documented informed consent, then completed the demographic information. Participants then completed the color match task, followed by the spatial match task.

## Registration and Analysis Plan

Prior to data collection, we pre-registered the method and analysis plan for this study was registered on the Open Science Framework (<https://osf.io/s6hc8/registrations>).

To summarize, we proposed to use Bayesian single case statistics, as implemented by the Dissocs\_Bayes\_ES.exe program available at <https://homepages.abdn.ac.uk/j.crawford/pages/dept/psychom.htm#dissocs> (Crawford et al., 2010) to compare the  $d'$  score for each posterior cortical atrophy patient to the group of elderly controls. The Bayesian single case statistics used transform the patient's score on each of two tasks into a Z-score, then compare that patient's performance to the distribution of the control group using a  $t$ -test. Then, the two tasks are compared using a Bayesian Specifically, we predicted that performance on the spatial task would exceed performance on the color task (using a one-tailed test). We also predicted that performance on schemas would exceed performance on images vs. words.

The only deviation we made from the pre-registration was that we collected five elderly control subjects rather than ten. We decided to halt data collection after the first five control subjects performed near ceiling on all aspects of the color and spatial tasks.

## Statistical Tools

Unless otherwise specified below (and except for the single case statistics tool), statistics were calculated using the `scipy` and `numpy` packages in Python (Oliphant, 2006, 2007). Data were manipulated with `Pandas` (McKinney, 2010) and visualized using `Matplotlib` (Hunter, 2007).

## Results

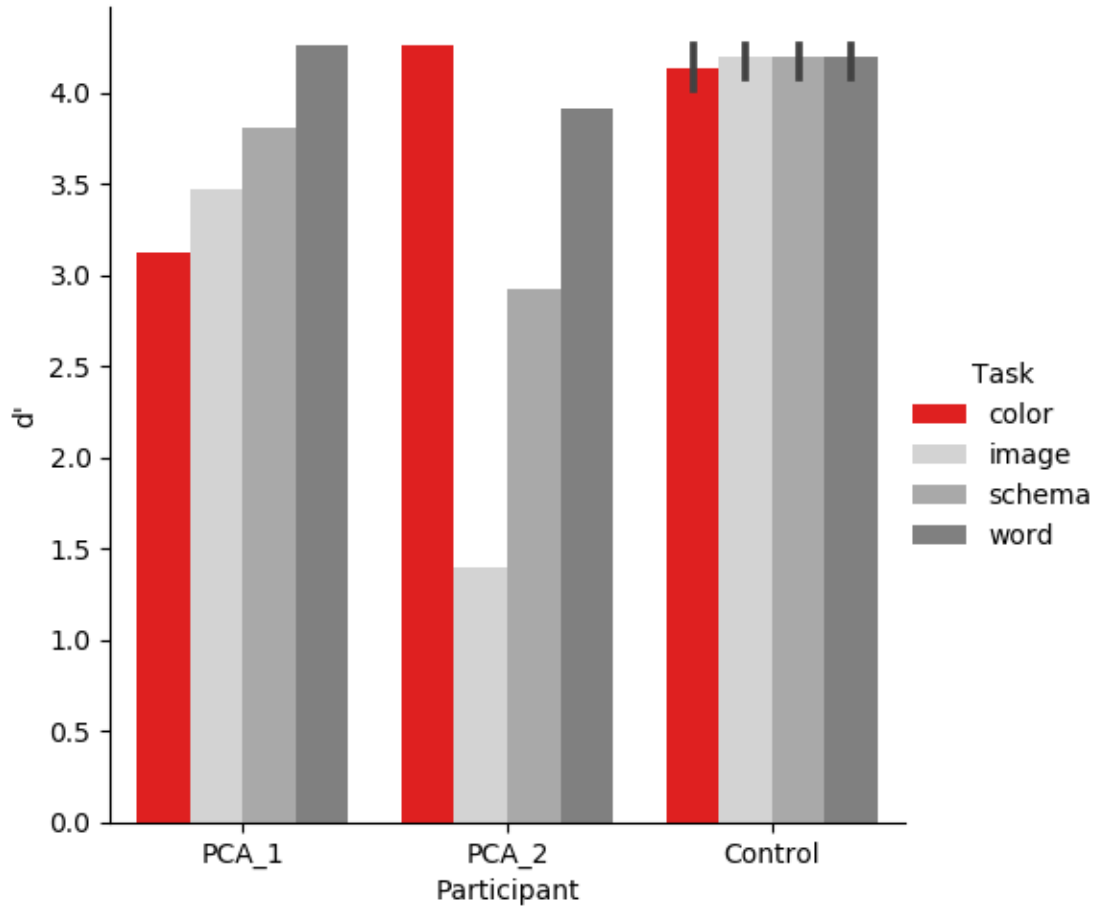
### Registered Analyses

**Comparing the color task and spatial task.** The purpose of the color task was to ensure that patients understood and could accommodate the memory and attentional demands of the task structure (i.e., could they follow instructions, remember the first stimulus, report same or different). Thus, we A) were not interested in deficits on the color task, and B) expected any deficits in spatial performance to be dissociated from the color task. For these reasons, we conducted a one-tailed single case test to determine whether each of the posterior cortical atrophy patients had deficits on the spatial task, which were dissociated from the color task.

Results reveal that PCA\_1 was significantly impaired on both the color and spatial task (Table 2, Figure 3). PCA\_2 was significantly impaired on the spatial task, but not on the color task (Table 2). Critically, this patient also showed a significant (putatively classical) dissociation between the color and spatial tasks (Table 3). (Although PCA\_1 was impaired on the color task, making their data difficult to interpret, PCA\_1 also did not show a significant dissociation between the two tasks (Table 3)). A classical dissociation (as distinct from a strong dissociation) means that the patient shows no deficit on one task compared to controls and shows a significant deficit on a second task compared to controls. A strong dissociation means the patient shows deficits on both tasks, but is significantly impaired on one task more than the other.

We next turned to analyze performance within the spatial task separately by format.





**Figure 3.** Performance (measured by  $d'$ ) on the color and spatial tasks for each patient and the control group.

*Table 2. Results of Bayesian dissociation analyses on  $d'$  assessing deficits on the spatial and color tasks separately.*

Task	Control sample			PCA_1's score	Significance test		Estimated percentage of the control population obtaining a lower score than the case		Estimated effect size ( $z_{cc}$ )	
	<i>n</i>	Mean	SD		<i>t</i>	<i>p</i>	Point	(95% CI)	Point	(95% CI)
Color task	5	4.14	0.16	3.12	-5.28	0.002	0.22	(0.00 to 1.76)	-6.38	(-10.72 to -2.11)
Spatial task	5	4.20	0.13	3.84	-2.53	0.03	3.24	(0.00 to 23.54)	-2.77	(-4.79 to -0.72)
				PCA_2's score						
Color task	5	4.14	0.16	4.26	0.57	0.30	70.06	(35.35 to 94.14)	0.63	(-0.38 to 1.57)
Spatial task	5	4.20	0.13	2.75	-10.18	0.0003	0.03	(0.00 to 0.007)	-11.15	(-18.66 to 3.82)

*Note.* Bayesian analyses examining whether each posterior cortical atrophy (PCA) patient showed a deficit on the color task and the spatial task. PCA\_1 showed deficits on both the color and spatial tasks. PCA\_2 showed a deficit on the color task but not the spatial task.

Table 3. Results of Bayesian dissociation analyses on *d'* comparing the spatial and color tasks.

Task	PCA_1 Dissociation	Bayesian test		
		<i>p</i>	Point	Estimated percentage of the control population obtaining a lower score than the case (95% CI)
Color vs. Spatial	None	0.08	4.04	(0.00 to 49.88)
	<u>PCA_2 Dissociation</u>			
Color vs. Spatial	Classical	0.0002	0.01	(0.00 to 0.00)

Note. Bayesian analyses comparing each posterior cortical atrophy (PCA) patient’s deficits on the color task compared to the spatial task. PCA\_1 did not show a dissociation. PCA\_2 showed a classical dissociation between the two tasks.

**Comparing performance across formats on the spatial task.** In our pre-registration, we predicted that PCA patients would show the strongest impairment on images and words compared to schemas. To test this, we ran a two-tailed single case test for each patient separately compared to the control group. Results showed that both patients experienced deficits compared to controls in comprehending spatial directions in schemas as well as words and images (Table 4). However, the effect was in opposite directions for PCA\_1 and PCA\_2 (see Tables 4 and 5 as well as Figure 3). PCA\_1 was significantly more impaired on schemas than words and images combined. PCA\_2 was significantly more impaired on words and images combined compared to schemas.

Because these results were not consistent with our prediction and because it is difficult to interpret PCA\_1’s data in light of his impaired performance on the color task, we proceeded to analyze single case statistics using PCA\_2’s data from the spatial task, comparing each format to every other. Here, we corrected for multiple comparisons using the Benjamin-Hochberg procedure as specified by our pre-registration (false discovery rate = .05, and total number of tests = 3).

Table 4. Results of Bayesian dissociation analyses on *d'* assessing deficits on schemas vs. words and images.

Task	Control sample			PCA_1's score	Significance test		Estimated percentage of the control population obtaining a lower score than the case		Estimated effect size ( $z_{cc}$ )	
	n	Mean	SD		t	p	Point	(95% CI)	Point	(95% CI)
Schemas	5	4.20	0.13	3.86	-2.39	0.04	3.77	(0.00 to 25.60)	-2.62	(-4.55 to -0.66)
Words + Images	5	4.19	0.13	3.8	-2.74	0.03	2.60	(0.00 to 20.68)	-3.00	(-5.16 to -0.82)
				PCA_2's score						
Schemas	5	4.20	0.13	2.65	-10.88	0.0002	0.02	(0.00 to 0.002)	-11.92	(-19.94 to -4.09)
Words + Images	5	4.19	0.13	2.93	-8.45	0.0005	0.05	(0.00 to 0.05)	-9.69	(-16.23 to -3.30)

Note. Bayesian analyses examining whether each posterior cortical atrophy (PCA) patient showed a deficit on schemas and on words and images on the spatial task. Relative to controls, PCA\_1 and PCA\_2 were impaired on schemas and (combined) words and images.

Table 5. Results of Bayesian dissociation analyses on  $d'$  comparing schemas vs. words and images.

Task	PCA_1 Dissociation	Bayesian test		Estimated percentage of the control population obtaining a lower score than the case	
		p	Point	(95% CI)	
Schemas vs. Words + Images	Strong (S > W+I)	0.0002	0.01	(0.00 to 0.00)	
	PCA_2 Dissociation				
Schemas vs. Words + Images	Strong (W+I > S)	0.00001	0.00	(0.00 to 0.00)	

Note. Bayesian analyses examining whether each posterior cortical atrophy (PCA) patient showed a deficit on schemas versus words and images. PCA\_1 had worse performance on words and images compared to schemas. PCA\_2 had worse performance on schemas compared to words and images.

The pattern of results was consistent across both patients. Both patients performed the worst on images and best on words. Schemas were significantly dissociated, strongly from images and classically from words for both patients. Results from PCA\_2 are presented in Tables 6 and 7.

Table 6. Results of Bayesian dissociation analyses on  $d'$  assessing deficits on images, schemas, and words.

Task	Control sample			PCA_2's score	Significance test		Estimated percentage of the control population obtaining a lower score than the case		Estimated effect size ( $z_{cc}$ )	
	n	Mean	SD		t	p	Point	(95% CI)	Point	(95% CI)
Images	5	4.20	0.13	1.39	-19.73	0.00002	0.00	(0.00 to 0.00)	-21.65	(-36.10 to -7.49)
Schemas	5	4.19	0.13	2.93	-8.92	0.0004	0.04	(0.00 to 0.04)	-9.77	(-16.36 to -3.33)
Words	5	4.20	0.13	3.91	-2.04	0.06	5.57	(0.004 to 31.32)	-2.23	(-3.93 to -0.49)

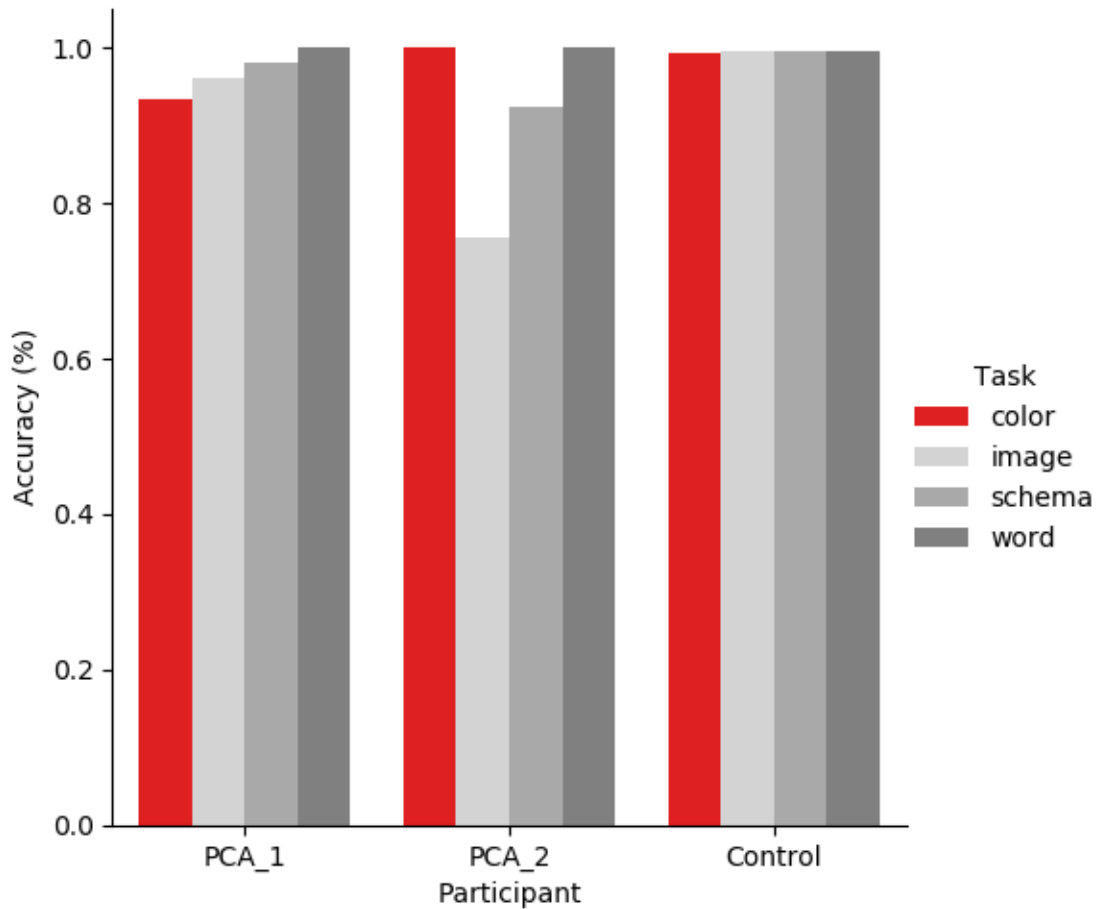
Note. Bayesian analyses examining whether each posterior cortical atrophy (PCA) patient showed a deficit for each format in the spatial task. The patient was impaired on images and

schemas, but not on words (Benjamini-Hochberg corrected critical value for the third statistical test,  $p = .015$ ).

*Table 7. Results of Bayesian dissociation analyses no  $d'$  comparing images, schemas, and words.*

<i>Task</i>	<i>PCA_2 Dissociation</i>	<i>Bayesian test</i> <i>p</i>	<i>Estimated percentage of the control population obtaining a lower score than the case</i>	
			<i>Point</i>	<i>(95% CI)</i>
Images vs. Schemas	Strong (I < S)	0.0005	0.00	(0.00 to 0.00)
Images vs. Words	Classical (I < W)	< .00001	0.00	(0.00 to 0.00)
Schemas vs. Words	Classical (S < W)	<.00001	0.00	(0.00 to 0.00)

Note. Bayesian analyses examining whether each posterior cortical atrophy (PCA) patient showed a deficit for each format compared to every other.



**Figure 4.** Performance (measured by accuracy) on the color and spatial tasks for each patient and the control group.

### Discussion

Despite spatial deficits, comprehending spatial directions in words and schemas is a process that is relatively spared in posterior cortical atrophy. In a pre-registered behavioral study in two patients with PCA, one patient was significantly impaired on a non-spatial color task, suggesting processing deficits that were not confined to spatial directions. A second patient showed a classical dissociation in the predicted direction: he was significantly impaired on the

spatial task, but had spared performance on the color task. This patient also showed dissociations among specific formats – words were unimpaired relative to schemas. Schemas were less impaired than images. These findings support the distinct aspects of spatial processing required by the three formats and provide a window into the role of the parietal lobes in comprehending spatial directions. This pattern of performance within the spatial task was not what we predicted in our pre-registration.

In the pre-registration, we predicted that schemas would be spared relative to words and images. Our prediction was based on prior research on PCA patients in which they have impairments on extracting relevant information from images (Crutch et al., 2012; Kas et al., 2011). Schemas, which contain and must be interpreted spatially, may have spared patients the most difficult aspects of spatial direction comprehension in images – extracting important visual cues from an informationally rich image while ignoring distracting or irrelevant details.

Consistent with the behavioral data we collected in healthy young adults, we interpret the current data to indicate that schemas serve as a middle ground, sharing characteristics with both words and images. Like images, the spatial content of schemas make them more difficult to match across varying perceptual forms. Like words, schemas are easier to parse from the visual scene. In part, this latter characteristic is because of the design of the stimuli used in this experiment – schemas and words were overlaid on a white background. In a control experiment conducted in healthy young adults, we overlaid the schemas and words on backgrounds created by phase-scrambling the images. Phase-scrambling preserves the visual information in the images but scrambles the content (the phase-scrambled images appear like military tree camouflage or tie-dye). In that experiment, we observed no reaction time differences when the phase-scrambled (compared to the white) backgrounds were used. Determining whether PCA

patients who show impairments on images also show impairments on schemas and words when they are overlaid on phase-scrambled images would be an important future direction.

On the other hand, the design of the current study enables us to say that the PCA patients we tested did not have difficulty matching concepts with varying visual features. Although impaired relative to elderly control participants (who were near ceiling on all measures), both PCA patients were above chance on all tasks and formats. And, even the PCA patient who was impaired on images could activate and compare, for example, a large, blue “LEFT” to a small, orange “left.” This finding could indicate the either preserved function of the intact structure of the parietal lobes for this patient, compensation by other brain regions critically involved in non-visual matching, or the lack of necessity of the parietal lobes for this task.

One limitation of the current study is that we do not know how the PCA patients we tested would perform in an ecologically-relevant navigational situation. The stimuli used in this study were static and non-immersive. Still, the data are consistent with the hypothesis that words, schemas, and images, for the matching task we used, are processed differently by the human brain. Overall, our findings suggest that PCA patients may struggle to interpret visually complex information, but might have an intact ability to compute spatial directions. These data could be critical in informing how to design spatial directions in real world environments that limit their visual complexity.

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