



## Research report

# Selective scene perception deficits in a case of topographical disorientation

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## ABSTRACT

Topographical disorientation (TD) is a neuropsychological condition characterized by an inability to find one's way, even in familiar environments. One common contributing cause of TD is landmark agnosia, a visual recognition impairment specific to scenes and landmarks. Although many cases of TD with landmark agnosia have been documented, little is known about the perceptual mechanisms which lead to selective deficits in recognizing scenes. In the present study, we test LH, a man who exhibits TD and landmark agnosia, on measures of scene perception that require selectively attending to either the configurational or surface properties of a scene. Compared to healthy controls, LH demonstrates perceptual impairments when attending to the configuration of a scene, but not when attending to its surface properties, such as the pattern of the walls or whether the ground is sand or grass. In contrast, when focusing on objects instead of scenes, LH demonstrates intact perception of both geometric and surface properties. This study demonstrates that in a case of TD and landmark agnosia, the perceptual impairments are selective to the layout of scenes, providing insight into the mechanism of landmark agnosia and scene-selective perceptual processes.

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## 1. Introduction

Topographical disorientation (TD) refers to a condition in which individuals are not able to find their way, often even in familiar environments. This condition can be caused by deficits relating to differing sub-processes involved in navigation,

such as the ability to orient oneself in an environment, the ability to form and remember spatial maps, and the ability to recognize and identify landmarks (Aguirre & D'Esposito, 1999; Barrash, 1998; Landis & Cummings, 1986). The latter is a common feature of TD, referred to as landmark agnosia, usually caused by lesions in the right or bilateral ventral occipitotemporal cortex, including the posterior

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parahippocampal cortex and anterior lingual gyrus (Aguirre & D'Esposito, 1999; Incisa della Rocchetta, Cipolotti, & Warrington, 1996; McCarthy, Evans, & Hodges, 1996; Mendez & Cherrier, 2003; Rainville et al., 2005; Takahashi & Kawamura, 2002).

In individuals with TD relating to landmark agnosia, basic perceptual abilities often are reported to be intact, but a profound deficit in the ability to recognize even very familiar environmental features is reported, resulting in way-finding deficits. It has been proposed that landmark agnosia, while not representing a global perceptual impairment, may stem from subtle perceptual deficits, which lead to specific difficulties in recognition and memory of landmarks (Aguirre & D'Esposito, 1999). Individuals with TD characterized by landmark agnosia often retain semantic knowledge of landmarks and map-based spatial memory. TD can also relate to other features than landmark agnosia, such as heading disorientation, in which individuals cannot derive directional information from landmarks but can still recognize them (Aguirre & D'Esposito, 1999; Hashimoto, Tanaka, & Nakano, 2010). Heading disorientation is accompanied by lesions in the retrosplenial cortex (Aguirre & D'Esposito, 1999; Hashimoto et al., 2010).

Landmark agnosia is distinct from other visual agnosias, such as form agnosia, caused by lesions in the lateral occipital cortex, in which individuals cannot visually recognize objects, but can still identify scenes (Steeves et al., 2004). In fact, in many cases of landmark agnosia, patients are reported to rely on their preserved object recognition abilities in order to compensate for deficits in scene recognition, often focusing on specific details such as windows or doorways in order to identify a particular scene (Aguirre & D'Esposito, 1999; Incisa della Rocchetta et al., 1996). Although many case studies of TD characterized by landmark agnosia have been reported, the underlying mechanism of this selective impairment is still not well understood. It is unknown what stage or what features of landmark recognition are impaired, rendering familiar scenes unrecognizable and hindering navigation abilities. Aguirre and D'Esposito (1999) proposed that individuals with TD and landmark agnosia may be specifically impaired at using high salience environmental features, and in arranging stimuli into scenes. Thus, it is possible that TD relating to landmark agnosia is caused by specific deficits to scene perception. Since basic visual skills and other forms of object and space perception are often intact in such cases, identifying what aspects of scene perception are impaired in cases of landmark agnosia and TD will provide insight into which perceptual processes are unique to the ability to perceive and recognize scenes, which is crucial for navigation.

One possibility is that the geometric or configural processing involved in scene perception is selectively impaired in cases of landmark agnosia and TD, though this has not previously been tested (Mendez & Cherrier, 2003; Rainville et al., 2005). This configural hypothesis is consistent with theories of the function of the parahippocampal place area (PPA), an area that is often damaged in cases of landmark agnosia. It has been proposed that this area is specialized for processing scenes based on features of their spatial layout (Epstein & Kanwisher, 1998). For example, early studies found that the PPA was more active when participants viewed scenes; this

was true even if the components of the scene were fractured as long as an intact layout configuration of scenes was maintained (Epstein & Kanwisher, 1998). When, however, the fractured components of the scene were rearranged, disrupting the layout, the activity in the PPA was reduced. The authors theorized that the role of the PPA, therefore, was to selectively encode the spatial layout of scenes (Epstein, 2008; Epstein & Kanwisher, 1998; Epstein, Higgins, Jablonski, & Feiler, 2007), and thus, damage to this area would be consistent with selective deficits in recognizing scenes due to an inability to process configural information.

Recent research, however, has highlighted other possible roles of the PPA in perceiving scenes, including a sensitivity to the texture or material properties of scenes and even objects (Cant & Goodale, 2007, 2011; Lowe, Gallivan, Ferber, & Cant, 2016). In two studies, objects of different surface and material properties (e.g., wood, marble, tinfoil) were presented and a region in the collateral sulcus (CoS), typically included in the PPA, was selectively active when participants attended to changes in the texture of the objects as opposed to their forms (Cant & Goodale, 2007, 2011). A more recent study utilizing scenes found robust activity in the PPA when participants attended to both layout and texture, though with increased activity to layout in manufactured scenes, where texture cues were thought to be less informative about the nature of the scene (Lowe et al., 2016). Thus, an alternative to the configural hypothesis is that TD with landmark agnosia may be derived from deficits in processing geometric properties of scenes, such as layout, as well as non-geometric properties including texture, since both are encoded by the PPA (Cant & Goodale, 2007, 2011; Epstein & Vass, 2014; Lowe et al., 2016).

In the present study, we tested LH, a man who developed topographical disorientation with landmark agnosia following bilateral posterior infarcts causing bilateral medial occipitotemporal damage. We tested LH's ability to discriminate perceptual changes pertaining to either the spatial layout or the surface texture of real-world scenes. We compared his performance to an object recognition task, where the shape and surface texture of the objects were varied. Thus, the present study examines whether the perceptual deficits associated with a case of landmark agnosia and TD are specific to either the configural properties or the surface properties of scenes, or both, and if they extend to similar properties in non-scene stimuli. These findings contribute to our understanding of the mechanisms underlying landmark agnosia and our certainty about which visual features are used to recognize scenes and navigate in everyday life.

## 2. Materials and methods

### 2.1. Participants

LH is male, with 21 years of education, and was 69 years old at the time of testing. Four years prior to testing (February 2011), LH developed topographical disorientation following a brain injury sustained during an automobile accident. Immediately following the injury, LH was reported to have bilateral posterior circulation infarcts and multiple foci of parenchymal and intracranial hemorrhage secondary to the trauma. He

underwent a left fronto-parietal craniotomy with subdural hemorrhage evacuation. An MRI exam in March 2011 showed evidence of a hematoma in the left parietal lobe, as well as a left frontal subdural hematoma and a trace right frontal subdural hematoma. In addition, cortical laminar necrosis was reported in the bilateral posterior and medial occipital lobes, and the left inferomedial parietal lobe. Follow-up imaging (October 2011) reported resolution of the hematomas, but sustained damage to the left parietal, left inferior temporal and bilateral occipital lobes, and the right cerebellar hemisphere (see Fig. 1, and Rivest, Svoboda, McCarthy, & Moscovitch, 2016). An additional follow-up scan conducted after testing (April 2015) reported no change from the October 2011 findings.

Immediately post-injury, LH was admitted to a rehabilitation center. Neuropsychological assessments reported that he performed in the superior range for IQ, vocabulary, working memory, conceptual reasoning, and visuo-constructional abilities. In contrast, his performance on measures of memory for prose and word-lists, semantic and phonemic fluency, naming, visual memory and visual object recognition were in the low average to average range (see Table 1 for details of neurocognitive profile, originally reported in Rivest et al., 2016). Following three months of rehabilitation, he demonstrated improvements in fine motor control, strength, speed of processing and memory, and was discharged from the rehabilitation unit (Rivest et al., 2016).

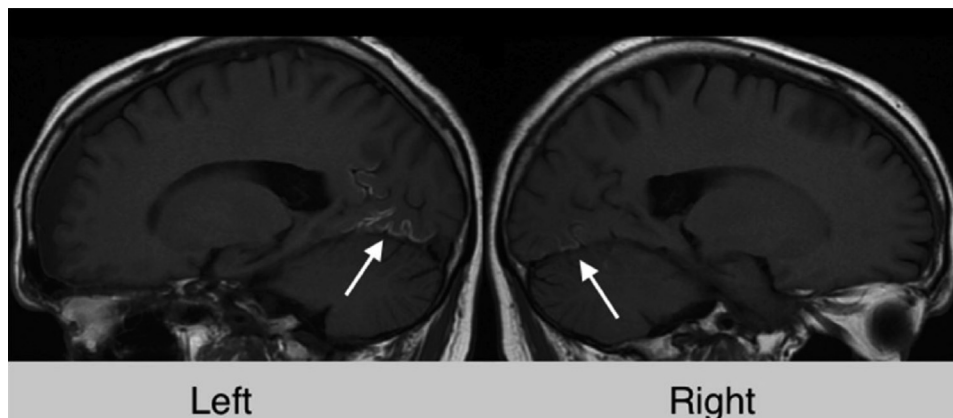
Despite these improvements, LH still demonstrated a profound topographical disorientation, from which he has not recovered. Even in familiar neighborhoods, he was not able to navigate independently or recognize familiar buildings, and frequently got lost (Rivest et al., 2016). For instance, he was unable to recognize the new building to which he moved after the accident, and could not navigate beyond the corner store. At this time, he was referred to a memory clinic at Baycrest. Further testing revealed that he is impaired at recognizing famous landmarks, locating cardinal directions, at discriminating colors and recognizing faces (Rivest et al., 2016)—all deficits which frequently co-occur with landmark agnosia (Aguirre & D'Esposito, 1999). In contrast, he can read maps, recognize objects, and read text. He performed normally on tests of visual memory and low-level perceptual abilities

(including judgments of line orientation, size, and length), and on tests of space perception and visuo-motor control. Although normal, his performance may still represent a decline as compared to his premorbid abilities based on his above average IQ. Based on Aguirre and D'Esposito's taxonomy of topographical disorientation (1999), clinical neuropsychologists speculated that LH's TD originates from a mixture of factors including landmark agnosia, heading disorientation and anterograde disorientation (Rivest et al., 2016). This assessment is consistent with the cause and location of LH's damage, since TD and landmark agnosia are commonly associated with posterior cerebral artery infarcts and damage in the medial occipital lobe (Aguirre & D'Esposito, 1999). Rivest et al. (2016) designed a clinical intervention during which LH was successfully trained to use dynamic maps on a smartphone in order to find his way and travel independently (Rivest et al., 2016). He can now navigate independently using his smartphone.

LH's performance in the present study was compared with that of eight male control participants, matched for age ( $M_{\text{age}} = 70.62$ ,  $SD = 6.28$ ; Crawford's  $t(7) = -.244$ ,  $p = .81$ ) and years of education ( $M_{\text{YOE}} = 17.5$ ,  $SD = 3.30$ ; Crawford's  $t(7) = .429$ ,  $p = .68$ ). All control participants had normal cognitive functioning, as measured by the Montreal Cognitive Assessment (MoCA) (Nasreddine et al., 2005); (all scores  $\geq 26$ ;  $M_{\text{MoCA}} = 28.13$ ,  $SD = 1.64$ ), and were native English speakers, with normal or corrected-to-normal vision and hearing, and no history of psychological or neurological illnesses or injuries.

## 2.2. Stimuli and procedure

The scene stimuli used here are from Lowe et al.'s study (2016) on scene perception in young healthy adults. Stimuli consisted of grayscale photographs from four scene categories (landscapes, caves, cityscapes, indoor rooms) representing four combinations of scene content (natural vs manufactured) and spatial boundary (open vs closed). For each category, 12 unique layouts were selected, resulting in different configurations of the scene, and 12 appropriate texture patterns (i.e., natural materials for the natural scenes, artificial materials for the manufactured scenes) were applied to the dominant



**Fig. 1** – High signal in the occipital gyriform areas as shown by 2011 MRI scan of LH. Cortical laminar necrosis was reported in the bilateral posterior and medial occipital lobes and left inferomedial parietal lobe (Rivest et al., 2016).

**Table 1 – L.H.'s neuropsychological results in 2011 and 2012. Tests accompanied by an \* were administered when L.H. was an inpatient at the rehabilitation center, all other tests were subsequently performed as part of a neuro-perceptual evaluation (Reproduced from Rivest et al., 2016).**

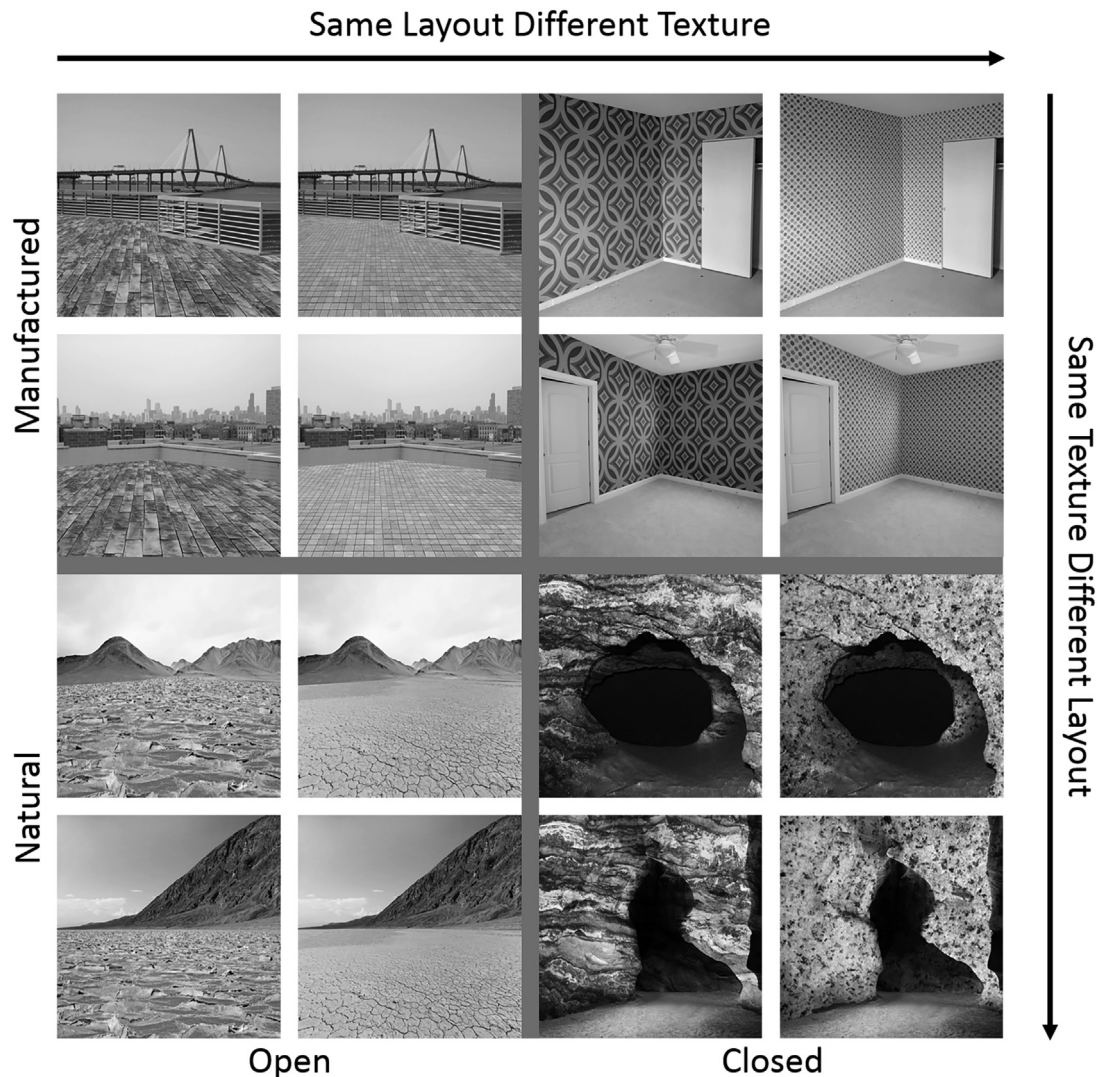
Cognitive abilities	Test names	Results
<b>General Intellectual Functioning</b>		
Verbal Intellectual Quotient (IQ)	Weschler Abbreviated Test of Intelligence*(WASI)	Verbal Intellectual Quotient (IQ): 136: Very Superior
Performance IQ	WASI	Performance IQ: 118: High Average
<b>Verbal Skills</b>		
Reasoning	Similarities; Weschler Scale of Intelligence-III* (WAIS-III)	Standard Score (SS): 12–16: High Average to Superior
<b>Memory</b>		
Semantic Memory	Vocabulary (WAIS-III)	SS: 14–15: Superior
Working Memory	Digit Span (WAIS-III)	SS: 13: High Average
Verbal Learning	Rey Auditory Verbal Learning Test*(RAVLT)	Z score (z): –.44: Average
Short Delay Recall	RAVLT	z: –1.50: Borderline
Delayed Recall	RAVLT	z: –1.05: Low Average
Recognition	RAVLT	z: .21: Average
Logical Memory	Weschler Memory Scale*	
Immediate Recall		SS: 11: Average
Delayed Recall		SS: 10: Average
<b>Fluency</b>		
Phonemic	CFL*	z: 0: Average
Semantic	Animals*	z: –1.24: Low Average
Naming to Visual Confrontation	Boston Naming Test* Kaplan Baycrest Neurocognitive Assessment (KBNA)	z: –1.03: Low Average with Word Finding Difficulties >16%ile: Normal
<b>Non Verbal Skills</b>		
Conceptual Reasoning	Matrix Reasoning (WAIS-III)	SS: 16–17: Superior
<b>Memory</b>		
Working Memory	Visual Span Backward (WAIS-III) Spatial Location (KBNA)	SS: 10: Average SS: 12: High Average
Learning	Rey Visual Design Learning Test* (RVDLT)	z: –1.39: Low Average
Delay Recall	Delayed Visual Reproduction (KBNA)	SS: 8: Average
Recognition	RVDLT Picture Recognition (KBNA) Complex Figure (KBNA)	z: –1.11: Low Average >16%ile: Normal SS: 10: Average
Visuo- constructional abilities	Block Design (WAIS-III) Complex Figure Copy-Clock Drawing (KBNA)	SS: 15–16: Superior SS: 16: Superior
<b>Visuo-Perceptual Abilities</b>		
Reading	Weschler Test of Adult Reading* (WTAR) Multilingual Aphasia Examination* (MAE)	Standard Score: 122: Superior 67%ile: Average
Line Orientation	Judgment of Line Orientation	Normal: Perfect score
Color Perception	Identification of 14 color patches Naming color of 10 familiar objects Farnsworth-Munsell 100-Hue Test	9 correct answers 10 correct answers but with hesitation Impaired color discrimination: Poor at all wavelengths
Object and Space Perception	The Visual Object and Space Perception Battery (VOSP)	Object Perception: Shape Detection Screening Test: Pass Incomplete Letters: Pass Silhouettes: Pass Object Decision: Pass Progressive Silhouettes: Fail Space Perception: Dot Counting: Pass Position Discrimination: Pass Number Location: Pass Cube Analysis: Pass
Recognition Faces	Delayed Visual Reproduction (KBNA) Benton Facial Recognition Test 35 pictures of well known individuals: Current Hollywood Actors, Canadian Politicians, and Hospital Staff members Faces of Famous People (80 faces: 20 per each last 4 decades; from Anaki, Boyd, & Moscovitch, 2007)	SS: 8: Average Normal Recognized 6 faces (did not recognize Hospital Staff members even when present in the testing room) Recognized 9 out of 45 known faces
Buildings	30 well known famous buildings Imagery (30 questions requiring comparisons of the buildings previously shown)	Recognized 11 17 correct answers

surface of each scene using Adobe Photoshop CS3 software. This resulted in 144 unique images per category, and 576 total images (see Fig. 2 for example scene stimuli). E-Prime 2.0 (Psychology Software Tools, Pittsburgh, PA) was used to present stimuli and to collect responses. Images were centrally presented on a white background at a size of  $500 \times 500$  pixels on an LCD laptop computer screen at a resolution of  $1024 \times 768$  and refresh rate of 60-Hz, at a viewing distance of approximately 70 cm.

Prior to starting data collection, participants provided informed consent to participate in the study. They were remunerated \$16/h for participation. This study was given ethics approval by the Baycrest Hospital Research Ethics Board. All participants were given detailed instructions with examples prior to starting the study, were given the opportunity to ask questions about the procedure, and then completed 16 practice trials to familiarize themselves with the task.

In the scene task, an instruction of either attending to the “Layout” or “Texture” was displayed for 5 sec, informing the participants to judge whether that aspect of the two

consecutive upcoming scenes matched or not. On each trial, a scene was displayed for 300 msec, followed by a 200 msec blank screen and then a second scene for 300 msec. A fixation cross was present throughout to encourage central fixation. After the second scene disappeared, a fixation cross remained on a blank screen for 3-s, during which time the participant pressed a key to indicate if the attended feature (i.e., layout or texture) was the same or different across the two scenes (pressing keys marked ‘S’ or ‘D’ on the keyboard to indicate same or different, respectively). Each block of eight trials used images from one scene category only (e.g., caves) and contained four same and four different trials presented in a random order. Each scene image appeared in one trial only. Each run contained a unique and counterbalanced order of eight blocks (one block of attending to each layout and texture for each of the four scene categories). For each trial, there were four possible outcomes: no change (NC), where the two pictures were identical; both change (BC), where both the layout and the texture changed between the pictures; layout change (LC), where the texture stayed constant but the layout changed; and texture change



**Fig. 2 – Examples of the four scene categories used. Scenes were defined by their spatial boundary (open vs closed) and content (natural vs manufactured) and varied according to layout and texture. Participants attended to either the texture or layout within a scene, either of which could change while the other was held constant (Lowe et al., 2016).**

(TC), where the layout stayed constant but the texture changed. Each block of eight trials contained two of each of these trial types, randomly ordered. These subcategories were used to analyze performance according to the specific demands of each type of trial and task instruction.

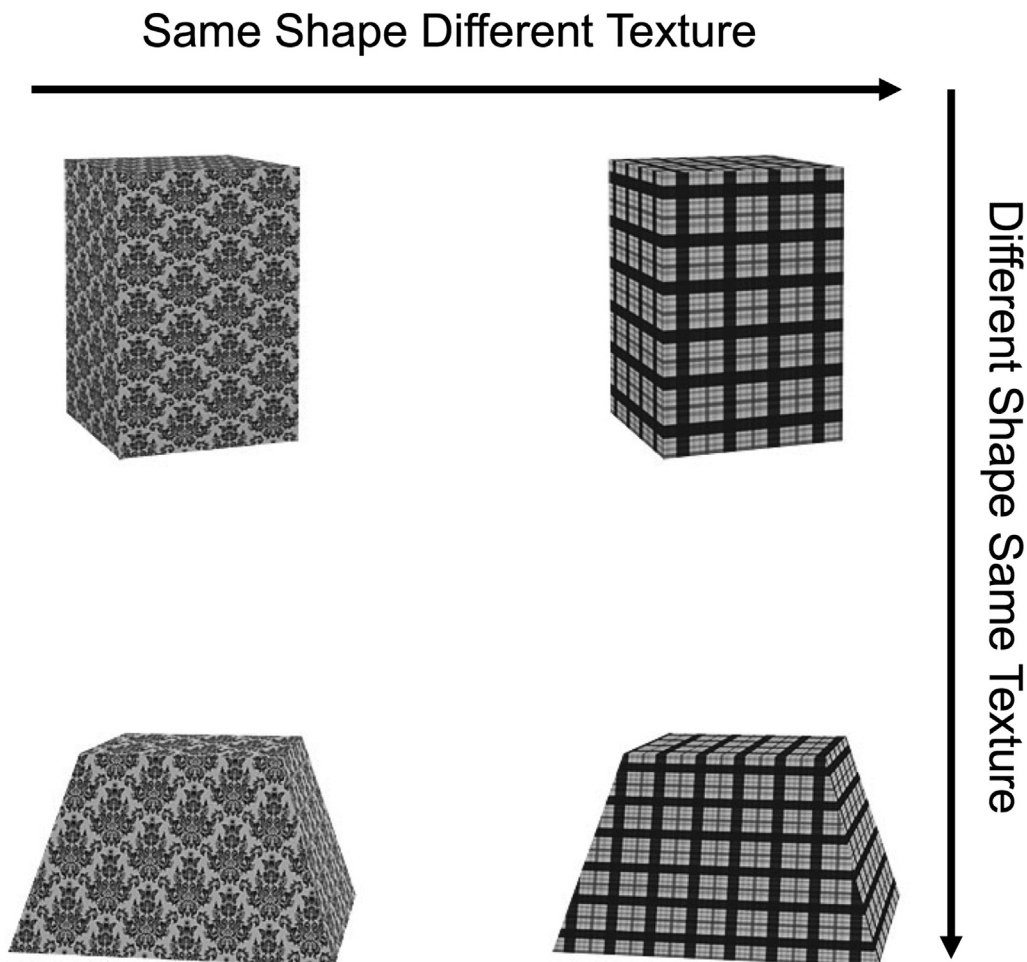
Participants completed four runs of 64 scene trials each, with short breaks between runs, for a total of 256 scene trials, resulting in 64 trials of each scene category, as well as 64 trials of each trial type (NC, BC, LC, TC). Due to a computer error, LH completed only 175 trials (total trials for each scene category: 39 landscapes, 48 caves, 48 cityscapes, 40 indoor rooms; total trials for each task: 87 layout, 88 texture; total trials for each trial type: 44 NC, 44 BC, 43 LC, 44 TC). We compared control performance for the first 175 trials to performance on the last 81 trials and found no difference in accuracy [ $M_{175} = 81.1\%$ ,  $SD = 12.8\%$ ;  $M_{81} = 80.9\%$ ,  $SD = 11.0\%$ ;  $t(7) = .08$ ,  $p = .94$ ], so all further analyses were performed based on the full set of control data.

Object stimuli were similar to the scene stimuli, but consisted of single grayscale objects centrally presented on white backgrounds. Objects were shaded to resemble 3D figures, and included 12 unique shapes (e.g., sphere, cone, cylinder, cube). The 12 texture patterns used for the manufactured scenes were applied to the objects, creating 144 unique object images (see Fig. 3 for example object stimuli).

The procedure for the object task was identical to the scene task, except that participants only completed one run, with a total of 64 trials, since there were no subcategories of objects. Trials were presented in blocks of eight, preceded by instructions to attend to either the “Shape” or “Texture” of the object. As with the scene task, each object was displayed on only one trial, and each block contained an equal number of same and different trials. All participants completed the scene task first, and then completed the object task. We chose not to counterbalance the order of the tasks in controls, but instead to match the order of the tasks across LH and all control subjects so that potential order effects would apply to all participants.

### 2.3. Statistical analyses

Accuracy scores (calculated as percent correct trials) and mean reaction times were computed for LH for each condition, according to the attended feature (Layout vs Texture for the scene task; Shape vs Texture for the object task) and a corresponding mean accuracy score and mean reaction time was calculated for the control group. For the scene task, accuracy was also calculated for each subtype of the scenes (natural vs manufactured; open vs closed) to determine if performance varied according to the types of scenes viewed.



**Fig. 3** – Examples of object stimuli used. Objects varied according to geometric shape and surface texture. Participants attended to either the texture or shape of the object, either of which could change while the other was held constant.

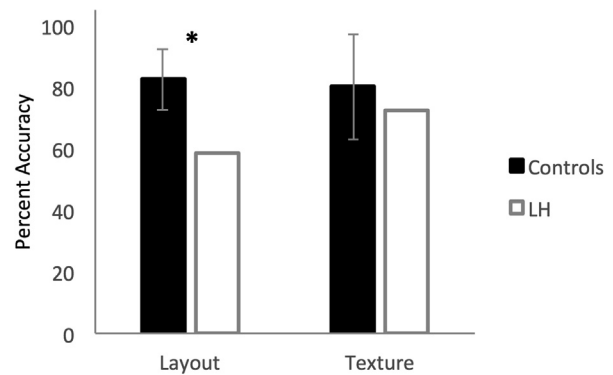
We further analyzed accuracy scores based on trial type and task instruction. While answering ‘same’ for NC trials and ‘different’ for BC trials would lead to accurate responses regardless of the attended feature, this was not the case for LC and TC trials, which were contingent on task instruction. Thus, if one was instructed to attend to layout, the correct answer would be ‘different’ for an LC trial, but this same trial in a block where one was attending to texture should produce a ‘same’ response. Analyzing the data in this way provides a more sensitive measure of which features were being used to make ‘same’ and ‘different’ decisions.

Crawford’s modified *t*-tests, designed for comparing single cases to control samples were used to compare accuracy scores and reaction times for LH and the control sample (Crawford & Garthwaite, 2002; Crawford & Howell, 1998). One-tailed tests were used since LH was expected to be impaired compared to controls on tests of perceptual discriminations of scenes. Though we did not predict impairments in the object condition, in order to avoid type II error (no difference between LH and controls), one-tailed tests were also used for analyzing the object perception results. Estimates of the effect sizes for the differences between LH’s scores and control means are reported using  $z_{CC}$  and an accompanying 95% confidence interval (CI) (Crawford, Garthwaite, & Porter, 2010). In order to compare differences in LH’s performance across two conditions with the average differences seen in the control group, we used the Revised Standardized Difference Test (RSDT), which tests if differences between conditions are significantly different in a single case as compared to a control sample (Crawford & Garthwaite, 2005; Crawford et al., 2010). Again, one-tailed tests were used based on predictions that LH would show larger differences across conditions than controls, and effect sizes for the differences with corresponding 95%CI are reported ( $z_{DCC}$ ).

### 3. Results

#### 3.1. Scene perception

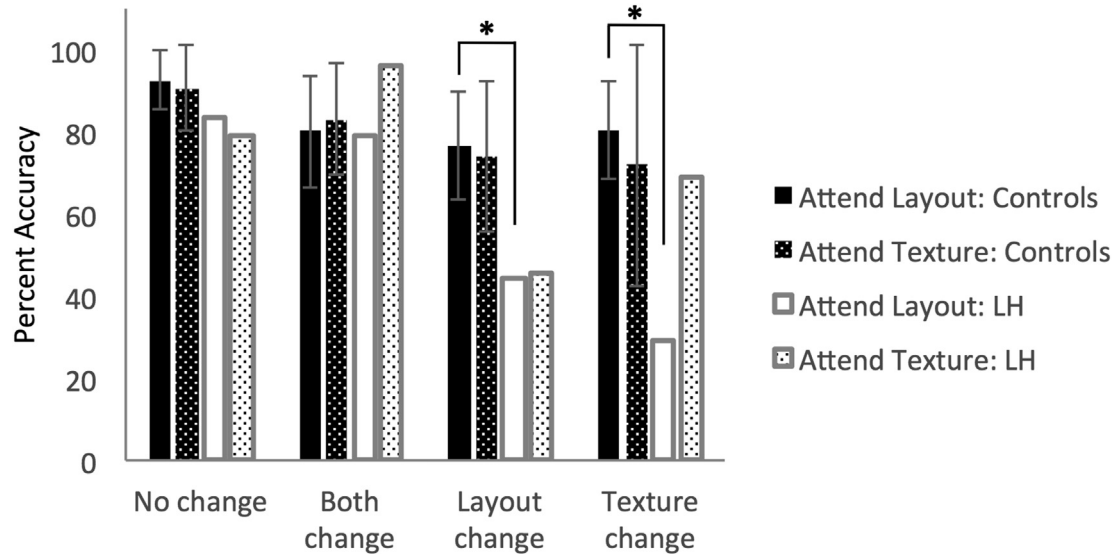
On the scene task, LH performed significantly less accurately than controls on judgments of layout changes [LH: 58.5%, Control mean = 82.5%, SD = 10.0%; Crawford’s  $t(7) = -2.272$ ,  $p = .029$ ,  $z_{CC} = -2.41$ , 95%CI (-3.808, -.978), Fig. 4]. In contrast, when making judgments of texture changes, LH’s performance was not significantly different from that of controls [LH: 72.7%, Control mean = 80.1%, SD = 17.1%; Crawford’s  $t(7) = -.407$ ,  $p = .348$ ,  $z_{CC} = -.432$ , 95%CI (-1.146, .309), Fig. 4]. The difference between LH’s accuracy in the layout versus texture conditions was marginally greater than the difference in the control sample as compared by the RSDT [ $t(7) = 1.818$ ,  $p = .056$ ,  $z_{DCC} = -2.213$ , 95%CI (-3.997, -.755)]. LH did not differ significantly from controls in terms of reaction time, either when attending to layout [LH: 1168.08 msec, Control mean = 991.23 msec, SD = 164.18 msec; Crawford’s  $t(7) = 1.018$ ,  $p = .171$ ,  $z_{CC} = 1.079$ , 95%CI (.170, 1.944)], or to texture [LH: 1144.89 msec, Control mean = 1020.54 msec, SD = 184.90 msec; Crawford’s  $t(7) = .668$ ,  $p = .262$ ,  $z_{CC} = .708$ , 95%CI (-0.094, 1.472)].



**Fig. 4 – Mean accuracy of LH and controls on the scene perception task. Error bars indicate standard deviation of the control sample. \*  $p < .05$ , one-tailed.**

Additional analyses showed that LH did not differ significantly from controls in terms of accuracy on any subset of scene type [Natural scenes – LH: 67.5%, Control mean = 82.6%, SD = 10.3%; Crawford’s  $t(7) = -1.393$ ,  $p = .103$ ,  $z_{CC} = -1.478$ , 95%CI (-2.482, -.428); Manufactured scenes – LH: 63.8%, Control mean = 80%, SD = 15.0%; Crawford’s  $t(7) = -1.083$ ,  $p = .171$ ,  $z_{CC} = -1.083$ , 95%CI (-1.949, -.172); Open scenes – LH: 61.3%, Control mean = 79.7%, SD = 14.0%; Crawford’s  $t(7) = -1.318$ ,  $p = .127$ ,  $z_{CC} = -1.318$ , 95%CI (-2.263, -.327); Closed scenes – LH: 69.9%, Control mean = 83.0%, SD = 11.0%; Crawford’s  $t(7) = -1.124$ ,  $p = .149$ ,  $z_{CC} = -1.193$ , 95%CI (-2.095, -.245)].

Analyzing the data by examining trial type and task instruction (see Fig. 5) revealed that LH did not perform significantly worse than controls on layout decisions in NC trials [LH: 83.3%, Control mean = 92.6%, SD = 7.1%; Crawford’s  $t(7) = -1.334$ ,  $p = .112$ ,  $z_{CC} = -1.414$ , 95%CI (-2.395, -.389)] and BC trials [LH: 79.2%, Control mean = 80.1%, SD = 13.7%; Crawford’s  $t(7) = -.069$ ,  $p = .473$ ,  $z_{CC} = -.073$ , 95%CI (-.765, .623)], where a correct decision could be made based on attending to either layout or texture. When attending to layout, however, LH performed poorly when there was a layout change but texture was kept constant [LC trials – LH: 44.2%, Control mean = 76.6%, SD = 13.0%; Crawford’s  $t(7) = -2.386$ ,  $p = .024$ ,  $z_{CC} = -2.531$ , 95%CI (-3.984, -1.046)], and especially poorly when a texture change occurred when attending to layout, performing below chance [TC trials – LH: 29.2%, Control mean = 80.5%, SD = 11.9%; Crawford’s  $t(7) = -4.044$ ,  $p = .002$ ,  $z_{CC} = -4.289$ , 95%CI (-6.582, -1.984)]. In contrast, when attending to texture, LH did not perform significantly worse than controls on any trial type, though performance appeared to be close to chance levels when attending to texture on LC trials [NC trials – LH: 79.2%, Control mean = 90.6%, SD = 10.6%; Crawford’s  $t(7) = -1.071$ ,  $p = .160$ ,  $z_{CC} = -1.136$ , 95%CI (-2.020, -.208); BC trials – LH: 95.8%, Control mean = 83.0%, SD = 13.7%; Crawford’s  $t(7) = .897$ ,  $p = .200$ ,  $z_{CC} = .951$ , 95%CI (.081, 1.777); LC trials – LH: 45.8%, Control mean = 74.1%, SD = 18.4%; Crawford’s  $t(7) = -1.522$ ,  $p = .097$ ,  $z_{CC} = -1.522$ , 95%CI (-2.543, -.456); TC trials – LH: 68.8%, Control mean = 71.9%, SD = 29.5%; Crawford’s  $t(7) = -.096$ ,  $p = .463$ ,  $z_{CC} = -.102$ , 95%CI (-.793, -.597)].



**Fig. 5 – Mean accuracy of LH and controls on the scene perception task, according to trial type. Error bars indicate standard deviation of the control sample. \*  $p < .05$ , one-tailed.**

### 3.2. Object perception

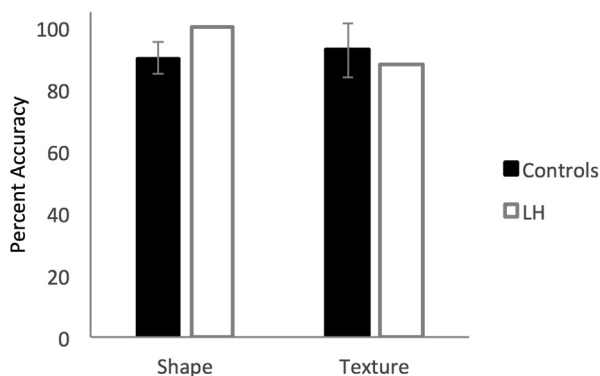
On the object task, LH obtained perfect accuracy on judgments of shape changes – a performance higher than the control mean in this condition [LH: 100%, Control mean = 90%, SD = 5.1%; Crawford's  $t(7) = 1.860$ ,  $p = .052$ ,  $z_{DCC} = 1.972$ , 95%CI (.727, 3.178), Fig. 5]. Importantly, the difference between LH's performance on configural judgments in scene (layout condition) and object tasks (shape condition) was significantly greater than the difference in the control sample as compared by the RSDT [ $t(7) = 2.679$ ,  $p = .002$ ,  $z_{DCC} = -3.124$ , 95%CI (-5.051, -1.489)]. In contrast, LH's accuracy on texture judgments in the object task did not differ from those of controls [LH: 88%, Control mean = 92.8%, SD = 8.8%; Crawford's  $t(7) = -.509$ ,  $p = .313$ ,  $z_{DCC} = -.540$ , 95%CI (-1.270, .223) Fig. 6] and his relative performance on the texture decisions in scenes versus objects was no different from controls, as compared by the RSDT [ $t(7) = .109$ ,  $p = .458$ ,  $z_{DCC} = .131$ , 95%CI (-.630, .904)]. LH also did not differ significantly from controls in terms of reaction time, when attending to shape [LH:

925.78 msec, Control mean = 852.75 msec, SD = 201.14 msec; Crawford's  $t(7) = .342$ ,  $p = .371$ ,  $z_{DCC} = .363$ , 95%CI (-.366, 1.069)], or when attending to texture [LH: 952.43 msec, Control mean = 915.24 msec, SD = 193.52 msec; Crawford's  $t(7) = .181$ ,  $p = .431$ ,  $z_{DCC} = .192$ , 95%CI (-.515, .885)]. We did not further analyze the object task data by examining trial type and task instruction due to the decreased number of trials in this task, and moreover, LH had intact performance on this task.

## 4. Discussion

The results from this study reveal a selective deficit in perceiving the layout of real-world scenes in a case of topographical disorientation characterized by landmark agnosia. When LH was asked to detect changes to the configuration of real-world scenes in different categories (i.e., landscapes, cityscapes, indoor rooms and caves), he was less accurate than controls and performed at close to chance levels, though his ability to detect changes in the dominant texture patterns (i.e., wallpaper pattern for indoor rooms, rock pattern for caves; if the ground was brick or tile for cityscapes, grass or sand for natural landscapes) of these same scenes was intact. Notably, his impaired performance on scene configuration was in contrast to his performance on a similar task involving single objects. These deficits appear to be specific to scenes, and do not extend to geometric decisions about non-scene stimuli. When discriminating the shape of objects, LH performed perfectly, demonstrating that his deficit does not apply to all geometric or configural decisions, and may be limited to complex scenes, or at least more complex conjunctions of features, which may help to explain his selective deficit in navigating and recognizing landmarks in the real world.

When further examining accuracy by trial type, a more nuanced pattern of deficits emerged, supporting the interpretation that LH is impaired at perceiving layout, but also highlighting the interaction of layout and texture in scene



**Fig. 6 – Mean accuracy of LH and controls on the object perception task. Error bars indicate standard deviation of the control sample.**



perception. When both texture and layout changed, or neither changed, LH performed at similar accuracy levels to controls, regardless of which feature was attended. This is notable since on these trials, he could have based his decision on either or both properties to obtain a correct response. When asked to attend to layout, however, LH performed poorly when layout was the only feature changed, and worse when texture changed (with scores below chance). This latter pattern of results may indicate an interaction between layout and texture perception, where LH relied on texture changes when responding, due to his poor ability to perceive layout changes. Thus, even though he was asked to attend to layout, noticing a change in texture may have caused him to classify these trials as different, despite no change to the layout.

LH's mostly intact performance when attending to texture suggests that his deficit is primarily in layout-based perceptual decisions of scenes. When attending to texture, LH did not perform significantly worse than controls for any trial type. Thus, it is not the case that general increased difficulty in the single feature change trials (i.e., LC and TC trials) led to decreases in performance for LH, since he performed similarly to controls when attending to texture in these trials. One caveat to LH's intact texture perception is that his accuracy at detecting a texture change when only a layout change occurred was close to chance, though this did not differ significantly from controls. This again may indicate an interaction between layout and texture perception, possibly indicating that LH is not completely insensitive to layout changes, though may have trouble identifying them as layout changes, thus mislabeling them as texture changes on these trials.

Thus, these results offer some support for the configural hypothesis, that the scene recognition deficits in TD with landmark agnosia are selectively related to impairments in perceiving the configuration or geometry of scenes (Mendez & Cherrier, 2003; Rainville et al., 2005), since LH is especially impaired at detecting layout changes in scenes. Considering that the PPA is frequently damaged in cases of landmark agnosia, these findings may also corroborate that the selectivity of its activity for processing scenes relates to configural processing of their layout, as has been proposed previously (Epstein & Kanwisher, 1998; Epstein et al., 2007; Epstein, 2008). It may be that when this area is damaged, configural processing becomes impaired, resulting in landmark agnosia and accompanying wayfinding deficits seen in topographical disorientation.

In addition, however, these findings also provide some evidence for the alternative hypothesis, that there is an interaction of configural and surface properties in scene perception, as shown by LH's misclassifications of changes in one of those properties for the other. In addition, LH performed best on trials in which both texture and layout changed, or neither, indicating that his performance was most accurate when texture and layout varied together, indicating improved perception when he was able to draw on both properties, despite his impairments in perceiving layout in isolation. Thus, although LH shows a more dominant deficit in layout perception, these data suggest an interaction between configural and surface properties in scene perception, and may support a role for the PPA in texture-based decisions, as has been shown in recent studies (Cant & Goodale, 2007, 2011;

Lowe et al., 2016). Since neural areas beyond the PPA are involved in texture perception, it is also possible that texture processing is more resilient to PPA damage. Previous findings on texture perception reported activity in a more posterior region of the CoS (pCoS) that does not overlap with the PPA (Cant & Goodale, 2011). It is possible that even with damage to the PPA, including the anterior CoS, texture perception abilities may be relatively preserved due to retained function in other texture-sensitive regions like pCoS, as may be the case in LH. While LH's deficits are consistent with PPA damage, it is important to note that the involvement of PPA here is speculative, as we cannot confirm if LH's PPA is damaged based on his available structural scans. Nonetheless, his behavioral deficits can still inform a mechanistic understanding of which perceptual processes are affected in cases of TD and landmark agnosia.

These results provide insight into the interplay of configural and surface features of scenes at the behavioral level, and how they jointly contribute to scene perception (Lowe et al., 2016; Oliva & Schyns, 1997; Oliva & Torralba, 2001, 2006). In healthy participants, it can be difficult to disentangle the contributions of these different features to scene perception, which may depend on their diagnosticity and relevance for the scene in question (Lowe et al., 2016; Oliva & Torralba, 2006). In contrast, LH demonstrates that in an individual who appears to have primary deficits to the perception of scene layout, there may be an increased reliance on using surface properties for distinguishing scenes. LH's intact performance in conditions which could be solved by relying on either structural or surface properties (NC and BC) demonstrates how relying on texture information can compensate for deficits in the detection of structural changes in real-world scenes, or exacerbate deficits when texture provides erroneous cues. Only when LH had to rely solely on the layout information to provide correct classifications were impairments evident; in particular, his below chance performance on layout decisions in the presence of texture changes suggests that even when cued to layout he relied on texture information to distinguish the scenes. This reliance on texture information may be indicative of how texture may contribute to the perception of scene layout, for example, by serving as a cue for differentiating the surfaces in a scene. The apparent increased reliance on texture information in LH is consistent with reports of increased reliance on surface properties including color and texture in an individual with visual form agnosia, who is unable to recognize objects based on their form, but uses color and texture information to compensate in both object and scene perception (Humphrey, Goodale, Jakobson, & Servos, 1994; Steeves et al., 2004).

When higher-level layout perception is impaired in individuals such as LH, texture cues may continue to be used to attempt to construct the layout of a scene. LH's difficulties in recognizing landmarks and navigating in known areas may stem from the fact that he is unable to appreciate the configuration of elements in his visual world, both at the level of landmarks and scenes as a whole. Thus, even if he is able to perceive individual elements of a scene, being unable to integrate them into a coherent whole would impair landmark recognition and could entail difficulties in perceiving the relationship between his own position and the broader

environment, resulting in the inability to find one's way. This interpretation is consistent with reports of landmark agnosia in which individuals can recognize scenes based on small features, such as the placement of a sign or the appearance of a door or window, but may be unable to mentally represent the scene as a whole (Aguirre & D'Esposito, 1999; Incisa della Rocchetta et al., 1996). While LH's deficits in layout perception may relate to the inability to integrate various features that make up the spatial configuration of a scene, we do not think that these deficits can be explained by a more general deficit in integration since LH can integrate visual elements in other situations, such as reading maps or perceiving the shapes of objects. One exception to this may be his deficit in face recognition, which could suggest that integrating features into configural representations for scenes and faces are mediated by proximate neural locations. Despite this proximity, Yovel and Kanwisher (2004) have provided evidence for distinct cognitive and neural mechanisms across face and scene perception (see also Anaki, Nica, & Moscovitch, 2011; on processing of faces and houses).

That LH's deficit was limited to the scene condition, with perfect performance on shape decisions in the object condition also supports the notion that he may be able to perceive the elements that make up scenes or landmarks, but be unable to process the configurations between them at a larger scale. His intact object perception also supports the hypothesized existence of scene-selective regions in the brain, including the PPA, and possibly the retrosplenial cortex (RSC) and occipital place area (OPA) (Epstein & Kanwisher, 1998; Epstein, 2008; Kanwisher, 2010; Park, Brady, Greene, & Oliva, 2011). An alternative possibility is that certain features, such as contour junctions (Walther & Shen, 2014; Walther, Chai, Caddigan, Beck, & Fei-Fei, 2011) or relative positions of items (Bohbot et al., 2015), are typically more prominent in scenes than in objects, and perception of these specific features are impaired in cases of TD with landmark agnosia, leading to the appearance of specific deficits in scene perception. Following this hypothesis, cases such as LH would be expected to also show perceptual impairments on non-scene stimuli that also contained these features in comparable number and complexity. The present findings cannot distinguish between these possibilities owing to the types of objects and scenes used as stimuli, where objects were holistic units that may have been easier to recognize and less perceptually demanding to process. Future research using more complex objects or more easily recognizable scenes may help to determine whether category-specific versus feature-specific models better explain the differences observed between scene and object perception.

#### 4.1. Conclusions

In summary, in order to better understand the perceptual deficits relating to TD with landmark agnosia, we tested case LH on scene and object perception tasks. The results showed that, compared to healthy controls, LH was impaired at detecting layout changes in real-world scenes. In contrast, LH was able to detect changes in their surface properties at levels comparable to controls, and was unimpaired at detecting both geometric and non-geometric changes in single objects. These

findings suggest that TD with landmark agnosia may relate to deficits primarily in configural processing of scenes, with subtler impairments in texture perception in situations in which texture and layout information conflict. Similar configural processing deficits may account for his difficulty in recognizing faces. This study thus provides novel insight into how surface and configural properties interact and jointly contribute to scene perception, which may help in discovering the underlying neural mechanisms of scene-selective areas in the brain, such as the PPA.

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