Brain & Language 126 (2013) 188–192

Contents lists available at SciVerse ScienceDirect

Brain & Language

journal homepage: www.elsevier.com/locate/b&l

Short Communication

How low can you go: Spatial frequency sensitivity in a patient with pure alexia ☆

Randi Starrfelt [a,*], Simon Nielsen [a,b], Thomas Habekost [a], Tobias S. Andersen [b]

[a] Center for Visual Cognition, Department of Psychology, University of Copenhagen, Denmark
[b] Department of Informatics and Mathematical Modeling, Technical University of Denmark, Copenhagen, Denmark

ARTICLE INFO

Article history:
Accepted 14 May 2013
Available online 15 June 2013

Keywords:
Pure alexia
Word length effect
Word reading
Case study
LBL-reading
Spatial frequency sensitivity
Contrast sensitivity

ABSTRACT

Pure alexia is a selective deficit in reading, following lesions to the posterior left hemisphere. Writing and other language functions remain intact in these patients. Whether pure alexia is caused by a primary problem in visual perception is highly debated. A recent hypothesis suggests that a low level deficit – reduced sensitivity to particular spatial frequencies – is the underlying cause. We tested this hypothesis in a pure alexic patient (LK), using a sensitive psychophysical paradigm to examine her performance with simple patterns of different spatial frequency. We find that both in a detection and a classification task, LK's contrast sensitivity is comparable to normal controls for all spatial frequencies. Thus, reduced spatial frequency sensitivity does not constitute a general explanation for pure alexia, suggesting that the core deficit in this disorder is at a higher level in the visual processing stream.

1. Introduction

Pure alexia is an acquired reading disorder that affects reading but not other language functions. Even writing is preserved, while reading is slow but mostly correct. A notable feature of pure alexia is the word length effect (WLE): Reaction times in reading increase linearly with word length for these patients, while in normal readers word length has little impact on reading times when words are shorter than five or six letters (Weekes, 1997; but see Cumming, Patterson, Verfaille, & Graham, 2006). The WLE is often interpreted as reflecting letter-by-letter (LBL) reading; the patients are thought to process letters serially rather than in parallel (e.g., Cohen et al., 2004).

The cognitive deficit underlying pure alexia is highly debated. Some argue that the disorder, at least in its purest form, affects reading only (e.g., Cohen et al., 2004; Gaillard et al., 2006; Yong, Warren, Warrington, & Crutch, in press) while others have suggested that a more general visual deficit causes the observed reading problems (Farah & Wallace, 1991; Fiset, Gosselin, Blais, & Arguin, 2006; Starrfelt, Habekost, & Leff, 2009). In general, the suggested "general visual deficit" thought to cause pure alexia has been relatively underspecified (although see Farah, 2004, for an exception). However, in 2006, building on several studies of patients with pure alexia/LBL-reading as well as experimental studies of normal subjects, Fiset et al. suggested a straightforward and testable hypothesis, namely that the LBL-reading pattern is caused by a reduced sensitivity to particular spatial frequencies. This reduced sensitivity is thought to affect medium-to-high spatial frequencies (Fiset et al., 2006; Tadros, Fiset, Gosselin, & Arguin, 2009) that are of particular importance for word recognition (Tadros, Dupuis-Roy, Fiset, & Arguin, 2010).

Anatomically, pure alexia has been linked to lesions in the left fusiform gyrus affecting the so-called visual word form area (VWFA; Cohen et al., 2004; Dehaene & Cohen, 2011; Leff, Spitsyna, Plant, & Wise, 2006; Starrfelt et al., 2009). Interestingly, a recent fMRI study has shown stronger activation to sine-wave gratings of high compared to low spatial frequencies in the VWFA, while the opposite was true for the corresponding areas in the right hemisphere (Woodhead, Wise, Sereno, & Leech, 2011). This led Woodhead et al. (2011) to suggest that spatial frequency sensitivity may be a potential locus of the visual deficit in pure alexia. The aim of the current study was to put this hypothesis to a direct test by investigating contrast sensitivity for different spatial frequencies in a patient with pure alexia and LBL-reading. If lack of sensitivity to certain medium or high spatial frequencies is important in causing this reading deficit, the patient should show selective impairment in performance with stimuli with these particular spatial frequencies, while sensitivity to other frequencies should remain intact or relatively preserved.

* Corresponding author. Address: Department of Psychology, University of Copenhagen, O. Farimagsgade 2a, DK-1351 Copenhagen K, Denmark. Fax: +45 35324802.
E-mail address: randi.starrfelt@psy.ku.dk (R. Starrfelt).

0093-934X/$ - see front matter © 2013 The Authors. Published by Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.bandl.2013.05.006

We report a study of patient LK, who shows the classical features of pure alexia: elevated reaction times (RTs) in single word reading, a significant word length effect, and preserved writing and language skills. The contrast sensitivity function (CSF) for LK and controls was determined in two different tasks. The spatial frequency hypothesis suggests that *sensitivity* for certain spatial frequencies should be affected in pure alexia, and thus testing our patients' ability to *detect* sinusoidal gratings of different frequencies at different contrast levels should be sufficient to test the hypothesis. However, as reading and letter identification demands not only detection of the important spatial frequencies, but also the ability to categorize or classify them, we decided to test LK's CSF in both a detection and a discrimination task. In the Detection task, participants had to detect the temporal interval in which a Gabor patch was presented, while in the Discrimination task, participants were asked to decide the orientation of a Gabor patch (horizontal or vertical).

2. Results

2.1. Participants

Patient LK was 29 years old at the time of this investigation (November 2011). She is right handed (Edinburgh handedness inventory laterality quotient + 100, Oldfield, 1971), and was studying for a Master's degree at the time of her injury (in 2008). At present, LK extensively uses computer software to compensate for her diminished reading skills. Following her partial recovery, she has finished her MA in philosophy, receiving the highest possible grade for her master's thesis! She has corresponded extensively with the authors using email, and her writing in this correspondence is flawless. She is now pursuing an academic career, in spite of her persistent reading problems.

An MRI performed at the time of this investigation revealed a lesion centred on the left occipito-temporal cortex (see Fig. 1). Posteriorly, the lesion affects lateral and inferior occipital cortex, with medial extension into the white matter at the depth of the calcarine sulcus. Moving anteriorly, the lesion affects the lateral part of the fusiform gyrus, the adjacent lateral occipitotemporal sulcus and the inferior temporal gyrus. The mid portion of the fusiform gyrus is spared, but the white matter above it (inferior longitudinal fasciculus including the inferior fronto-occipito fasciculus) is affected. The most anterior extent of the lesion is level with the most posterior part of the splenium of the corpus callosum. There is also evidence that an external ventricular drain was placed at some point through the right frontal lobe, with some focal damage of the genu of the corpus callosum.

LK's performance was compared to 10 control participants, matched for age (LK = 30; controls = 31.5 (SD = 2.5), educational degree (MA), final grade (LK = 12; controls = 10.9 (SD = 1.5), and handedness (right). All controls had normal or corrected to normal vision, and no history of neurological or psychiatric illness or dyslexia. LK and the control participants gave informed written consent according to the Helsinki Declaration to participate in the study, and approval was given by the Biomedical research ethics committee in Copenhagen (KF 01-258988).

2.2. Background testing

In 2009–2010, preliminary testing in our lab revealed that LK showed elevated reaction times in word reading, a significant word length effect, and slow and effortful text reading. She made very few reading errors. Her writing was flawless, as evidenced by writing sentences and single words (PALPA subtest 31). In 2010, LK's reaction times (RTs) in naming 40 Snodgrass and Vanderwart (1980) line drawings were significantly elevated (LK's mean RT was 1040 ms, mean (SD) of a group of 14 elderly controls are 770 (84), $t = 3.335$; $p = .003$, Crawford and Howell's test; see Starrfelt, Habekost, & Gerlach, 2010 for a description of this task). Her visual fields were tested with a computerized perimetry (Kasten, Gothe, Bunzenthal, & Sabel, 1999), where she responded to all stimuli in both visual fields, indicating that the hemianopia previously noted had remitted. In a test of visual attention for peripheral visual stimuli (Whole report, see Starrfelt et al., 2010 for details), LK's visual processing speed for letters was found to be impaired, particularly at two positions in the upper right quadrant, where

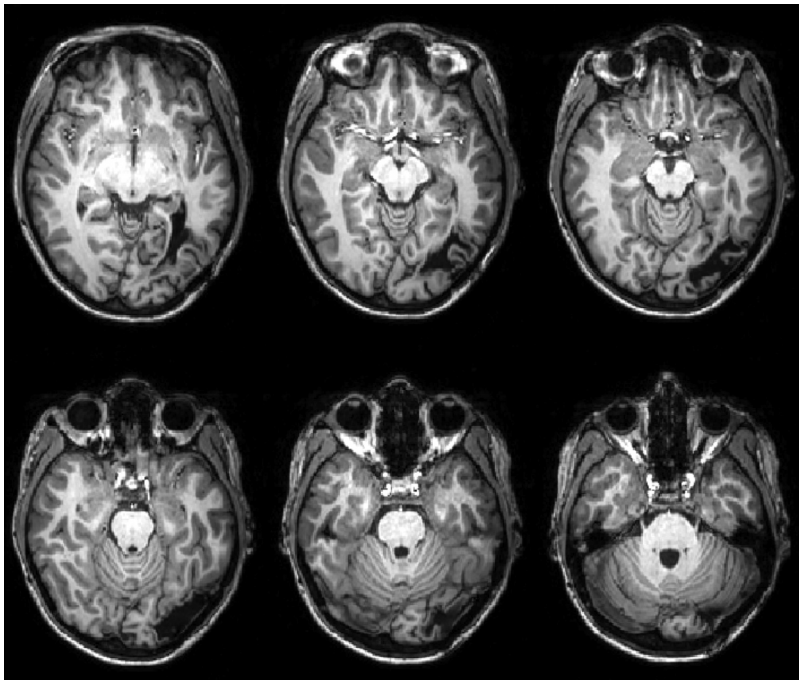

Fig. 1. MRI-scan of LK's lesion in the left occipito-temporal cortex (see text for anatomical description).