Neuropsychologia 56 (2014) 245–254

Contents lists available at ScienceDirect

Neuropsychologia

journal homepage: www.elsevier.com/locate/neuropsychologia

Hallucinators find meaning in noises: Pareidolic illusions in dementia with Lewy bodies

Kayoko Yokoi [a], Yoshiyuki Nishio [a,*], Makoto Uchiyama [b], Tatsuo Shimomura [c], Osamu Iizuka [a], Etsuro Mori [a]

[a] Department of Behavioural Neurology and Cognitive Neuroscience, Tohoku University Graduate School of Medicine, 2-1 Seiryo-machi, Aoba-ku, Sendai 980-8575, Japan
[b] Department of Speech, Language and Hearing Sciences, Niigata University of Health and Welfare, 1398 Shimami-cho, Kita-ku, Niigata 950-3198, Japan
[c] Department of Rehabilitation Medicine, Akita Prefectural Centre of Rehabilitation and Psychiatric Medicine, 352 Kyowakamiyodokawa, Daisen 019-2413, Japan

ARTICLE INFO

Article history:
Received 7 September 2013
Received in revised form
22 January 2014
Accepted 24 January 2014
Available online 31 January 2014

Keywords:
Visual illusions
Visual hallucinations
Acetylcholine
Dementia with Lewy bodies
Pareidolias

ABSTRACT

By definition, visual illusions and hallucinations differ in whether the perceived objects exist in reality. A recent study challenged this dichotomy, in which pareidolias, a type of complex visual illusion involving ambiguous forms being perceived as meaningful objects, are very common and phenomenologically similar to visual hallucinations in dementia with Lewy bodies (DLB). We hypothesise that a common psychological mechanism exists between pareidolias and visual hallucinations in DLB that confers meaning upon meaningless visual information. Furthermore, we believe that these two types of visual misperceptions have a common underlying neural mechanism, namely, cholinergic insufficiency. The current study investigated pareidolic illusions using meaningless visual noise stimuli (the noise pareidolia test) in 34 patients with DLB, 34 patients with Alzheimer's disease and 28 healthy controls. Fifteen patients with DLB were administered the noise pareidolia test twice, before and after donepezil treatment. Three major findings were discovered: (1) DLB patients saw meaningful illusory images (pareidolias) in meaningless visual stimuli, (2) the number of pareidolic responses correlated with the severity of visual hallucinations, and (3) cholinergic enhancement reduced both the number of pareidolias and the severity of visual hallucinations in patients with DLB. These findings suggest that a common underlying psychological and neural mechanism exists between pareidolias and visual hallucinations in DLB.

1. Introduction

In our everyday life, we believe that we instantaneously recognise the physical features of objects in the external world through vision. However, psychologists and neuroscientists have demonstrated that our instantaneous visions are often unreliable and that object recognition depends on context, prediction and proactive inference (Bar, 2007; Friston, 2005; Kersten, Mamassian, & Yuille, 2004). Misperceptions associated with a variety of neurological and psychiatric diseases, e.g., hallucinations and illusions, are classic examples of what occurs when these types of active aspects of perception do not work. For example, patients with schizophrenia would believe hallucinatory voices to be tricks and be less annoyed if the underlying context or premise that no one possesses the ability to transfer his/her voices through electrical waves was not corrupted (Frith & Done, 1988; Kapur, 2003).

Dementia with Lewy bodies (DLB) is presumably one of the most common disorders that causes visual misperceptions. Approximately 80% of patients with DLB reportedly experience visual hallucinations (Luis et al., 1999; McKeith et al., 1996). Uchiyama et al. (2012) recently showed that pareidolias, which are complex visual illusions involving ambiguous forms perceived as meaningful objects, are quite common in DLB and are even observed in DLB patients not experiencing visual hallucinations. What is the difference between a visual hallucination and a pareidolia? By definition, visual hallucinations are perceptions without real perceptual objects. In contrast, the pareidolias observed in the previous study (Uchiyama et al., 2012) arose from pictures containing visual scenes with contexts or meanings. Therefore, these conditions differ regarding whether the perceptual objects exist in reality (Ey, 1973). Based on this point of view,

* Corresponding author. Tel.: +81 22 717 7358; fax: +81 22 717 7360.
E-mail address: nishiou@med.tohoku.ac.jp (Y. Nishio).

0028-3932/$ - see front matter © 2014 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.neuropsychologia.2014.01.017

we hypothesised that an intermediate condition exists between these two conditions: seeing something meaningful in meaningless visual patterns. In the current study, we developed a test that evoked this particular type of misperception, which we termed the noise pareidolia test, and we administered this test to patients with DLB. If patients falsely observe meaningful objects in meaningless visual stimuli, this finding would support the hypothesis that similarities and continuity exist between visual hallucinations and pareidolias along with the existence of an abnormal proactive perceptual process in misperceptions in DLB.

Pareidolias and visual hallucinations are behaviourally similar phenomena, and whether the two conditions share common neural mechanisms remains unknown. One of the well-known mechanisms of visual hallucinations in DLB is cholinergic insufficiency. Previous neuropathological and neuroimaging studies have demonstrated that cholinergic neuronal degeneration is more severe in patients with DLB or Parkinson's disease (PD) who experience visual hallucinations (Ballard et al., 2000; Halliday, 2005; Harding, Broe, & Halliday, 2002; Perry et al., 1990). The effectiveness of cholinesterase inhibitors on visual hallucinations has been established by several intervention studies (McKeith et al., 2000; Mori et al., 2012; Mori, Mori, Iseki, & Kosaka, 2006). In the current study, we performed a longitudinal analysis on pareidolias before and after the treatment with donepezil to investigate whether cholinergic mechanisms are involved in both pareidolias and visual hallucinations.

2. Methods

2.1. Participants

We recruited 34 patients with probable DLB and 34 with probable Alzheimer's disease (AD) from the dementia clinics at the Tohoku University Hospital, the Akita Prefectural Centre of Rehabilitation and Psychiatric Medicine and the Minami Tohoku Hospital. Twenty-eight healthy controls (HC) were recruited from the local community through an advertisement. There was no overlap between the subjects included in the current study and those in our previous study (Uchiyama et al., 2012). The three groups were comparable in age, sex and visual acuity. The severity of cognitive impairment, which was assessed by the Mini-Mental State Examination (MMSE) (Folstein, Folstein, & McHugh, 1975), was matched between the DLB and AD groups (Table 1). All patients underwent an examination by experienced behavioural neurologists, an MRI and routine laboratory investigations. Probable DLB was diagnosed according to the international workshop criteria of DLB (McKeith et al. 2005), and probable AD was diagnosed based on the standard guidelines set by the National Institute of Neurological and Communicative Disorders and Stroke and the Alzheimer's Disease and Related Disorders Association criteria (McKhann et al., 1984). The exclusion criteria were as follows: (i) a history of other neurological or psychiatric diseases or of severe ocular diseases, (ii) a best-corrected acuity of at least 0.4 (LogMAR) and (iii) language deficits hindering task executions. At the time of the examination, nine patients with DLB were treated with donepezil, three were treated with levodopa, two were treated with quetiapine, and one was treated with pramipexole. In the AD group, 24 patients were treated with donepezil, four were treated with trazodone, two were treated with fluvoxamine, and one was treated with risperidone. The demographic and clinical characteristics of the participants are summarised in Table 1.

2.2. Background neuropsychological and behavioural assessments

The Digit Span and Spatial Span subtests from the Japanese version of the Wechsler Memory Scale-Revised test (Sugishita, 2001) were used to assess attention/working memory. Visuoperceptual and visuospatial functions were assessed using the Shape Detection Screening and Position Discrimination subtests of the Visual Object and Space Perception battery (Warrington & James, 1991), the Object Decision subtest (Easy B) of the Birmingham Object Recognition Battery (Riddoch & Humphreys, 1992) and the Face Recognition subtests (face-to-face matching of unknown faces, same/different judgment of unknown faces in different views, gender and age judgments of unknown faces) of the Visual Perception Test for Agnosia (Japan Society for Higher Brain Dysfunction Brain Function Test Commitee, 1997). The Japanese versions of the Frontal Assessment battery (FAB) (Kugo et al., 2007) and the Phonological Verbal Fluency (Fu/A/Ni) test were used to assess executive functions.

The Neuropsychiatric Inventory (NPI) (Cummings et al., 1994) was administered to the caregivers of the patients. The original NPI consists of the following 10 behavioural domains: delusions, hallucinations, dysphoria, anxiety, agitation/aggression, euphoria, disinhibition, irritability/lability, apathy, and aberrant motor activity. We made several modifications to the original NPI. First, the 'delusion' domain was separated into two different categories: persecutory delusions and delusional misidentifications. The questions regarding the former included 'believing that others are planning to hurt him/her' and 'believing that others are stealing from him/her', and the questions regarding the latter included 'believing that unwelcome guests are living in the house', 'believing that television or magazine figures are actually present in the home' and 'believing that patient's family is an imposter'. Second, we employed an additional domain for fluctuations in cognition, which included questions such as 'does the patient sometimes show a lack of attention or a slow reaction to others' calls than usual?' and 'does the patient sometimes show a poor understanding of things that he can usually understand?' (Mori et al., 2006). A total of 12 domains of neuropsychiatric symptoms were evaluated based on the clinical status of patients during the past one month. The frequency (range 1–4), severity (1–3) and domain total scores (the product of the frequency score multiplied by the severity score) were recorded for each behaviour.

2.3. The pareidolia tests

2.3.1. The noise pareidolia test

Examples of the stimuli are shown in Fig. 1. Two versions of the noise pareidolia tests were developed: the object version and the face version. The object version was used to investigate the content of pareidolic illusions, and the face version was employed because previous studies demonstrated that human faces are one of the most frequent subjects of pareidolias and visual hallucinations (Ballard et al., 1997; Uchiyama et al., 2012). Both versions consist of 40 black and white images (16×16 cm^2) with a spatial frequency of $1/f^3$ (Fig. 1A). We chose this specific frequency for two reasons: (1) previous studies have demonstrated that the power spectra of natural images conform to $1/f^n$, where f is the spatial frequency and the parameter n varies at approximately 2 (Field, 1987; Ruderman, 1994), and (2) our preliminary experiments showed that an image with a $1/f^3$ frequency best discriminated patients experiencing visual hallucinations from the HC. In the object version, silhouette images of objects (two whole bodies of humans, two animals, two plants and two man-made objects) were embedded in 8 of the 40 stimuli (Fig. 1B). In the face version, black and white images of human faces were embedded in 8 of the 40 stimuli (Fig. 1C).

Immediately before administering the tests, a detailed explanation and three training trials were given to the participants. In the object version, the participants were instructed to state whether an object or nothing was present in each stimulus. When the participants saw an object, they were asked to point at and name the object. In the face version, the participants were instructed to state whether a face was present in each stimulus. When the participants observed a face, they were requested to point at it.

The responses of the participants were classified into three types: (1) illusory responses, in which the subjects falsely found objects or faces at locations where the object or face images did not actually exist, (2) detection misses, in which the subjects did not detect the embedded face or object images, and (3) correct responses, in which the participants correctly responded "nothing exists" to the noise stimuli or correctly detected the embedded images in the stimuli containing the object or face images. We did not use the correct responses for analysis because these selections were nearly equivalent to the total number of stimuli (40) minus the sum of the illusory responses and detection misses. To conduct a phenomenological analysis of pareidolias using the object version, the contents of the illusory responses were classified into five categories: (1) people, (2) animals (e.g., dogs, birds and insects), (3) plants (e.g., vegetables and flowers), (4) man-made objects, and (5) other (e.g., letters and footprints). The order of administration of the two versions was counterbalanced across the participants.

2.3.2. The scenery pareidolia test

To evaluate concurrent validity between the newly developed noise pareidolia test and the one used in our previous study, the pareidolia test with scenery pictures (Uchiyama et al., 2012), was administered to 11 patients with DLB.

2.4. Statistical analysis

A one-way analysis of variance (ANOVA) and a post-hoc Scheffe test were used for the between-group comparisons of the pareidolia test and other neuropsychological tests. The Mann–Whitney U-test was used for the between-group comparisons of the NPI subscores. A receiver operating curve (ROC) analysis was used to evaluate the ability of the tests to differentiate DLB from AD. To investigate the relationships among illusory responses, stimulus detection sensitivity and response bias, the sensitivity (d') and response bias (c) were calculated according to signal detection theory: $d' = Z(\text{hit rate}) - Z(\text{illusory response rate})$; $c = -(Z(\text{hit rate}) + Z(\text{illusory response rate}))$ (Macmillan & Creelman, 1990). The group-wise comparisons were conducted using a one-way ANOVA. The relationship between the performance during the pareidolia tests and other neuropsychological and behavioural variables was assessed using Pearson's correlation coefficient or Spearman's rank correlation coefficient. To evaluate the