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Specific vulnerability of face perception to noise: A similar effect in schizophrenia patients and healthy individuals

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ABSTRACT

Face perception plays a foundational role in the social world. This perceptual ability is deficient in schizophrenia. A noise-filtering mechanism is essential for perceptual processing. It remains unclear as to whether a specific noise-filtering mechanism is implicated in the face perception problem or a general noise-filtering mechanism is involved which also mediates non-face visual perception problems associated with this psychiatric disorder. This study examined and compared the effects of external noise on the performance of face discrimination and car discrimination in schizophrenia patients ($n=25$) and healthy controls ($n=27$). Superimposing the external visual noise on face or car stimuli elevated perceptual thresholds (i.e. degraded performance levels) for both face and car discrimination. However, the effect of noise was significantly larger on face than on car discrimination, both in patients and controls. This pattern of results suggests specific vulnerability of face processing to noise in healthy individuals and those with schizophrenia.

1. Introduction

Schizophrenia patients have exhibited impairments in various aspects of face perception (Phillips and David, 1995; Mandal et al., 1998; Darke et al., 2014; Chen, 2011). While impairments in face perception must have profound impacts on social functioning (Barton, 2003; Duchaine and Nakayama, 2005), their underlying mechanisms remain murky. Previous studies have been focused on how different functional domains such as affective and non-affective processing of facial images are altered in schizophrenia patients (Heimberg et al., 1992; Gur et al., 2002; Butler et al., 2008; Chen et al., 2008, 2009; Silverstein et al., 2010; McBain et al., 2010; Lee et al., 2007, 2011; Yoon et al., 2006). Noise-filtering is essential for the processing of perceptual information including faces, and appears to be implicated in various aspects of deficient perceptual processing in schizophrenia (Chen et al., 2008, 2014; Kim et al., 2013). A recent study proposed heightened noise levels as a mechanism underlying abnormal facial processing in schizophrenia (Spencer et al., 2013). The premise of this empirically- and computationally-inspired proposal is that noise within the facial processing system is heightened in this psychiatric disorder and, as a result, the reduced signal-to-noise ratio degrades patients' capacity in face perception.

Noise is a critical limiting factor for information processing in the brain; yet it is unclear whether it plays a similar role across different brain systems. The brain system for processing face information is distinct from those for processing non-face visual information. For example, the fusiform face area (FFA) of the temporal cortex responds selectively to faces, but not to non-face visual objects (Kanwisher et al., 1997, 1998; Haxby et al., 2000). As to noise, the existence of the face-specific brain system bears a question whether face processing, compared to the processing of non-face visual objects, responds differently to signal-irrelevant inputs. This question has not been answered with respect to either schizophrenia patients or healthy individuals.

In this study, we examined the effects of external noise on face discrimination and car discrimination in healthy individuals and schizophrenia patients. Our working hypothesis was that imposing external noise would interfere with the performance of face discrimination task to a greater extent than of car discrimination task, assuming that face processing is more vulnerable to noise than non-face visual processing. Further, given that schizophrenia is associated with hypersensitivity to environment (with a tendency to register information of no intrinsic interest) (Bleuler, 1911), we hypothesize that imposing external noise would interfere with patients' performance of face discrimination task to a greater extent than among controls.

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2. Material and methods

2.1. Subjects

Participants included 25 schizophrenia patients and 27 healthy controls. These individuals were included based on the following criteria: (1) no history of any neurological disorders (such as seizure or stroke) or head injuries, (2) IQ > 70, (3) age between 18 and 60 years old, and (4) no substance abuse in the six months prior to participation.

Patients were recruited from McLean Hospital and the Greater Boston areas. Their diagnoses were established based on a structured clinical interview SCID-IV (First et al., 1994) conducted by experienced clinicians who were blind to the purposes of this study, and by a review of all available medical records. Thirteen of these patients had a diagnosis of schizophrenia and the rest had a diagnosis of schizoaffective disorder. All patients were medicated on antipsychotic drugs (mean CPZ=538.1 mg, SD=422.7 mg). The Positive and Negative Syndrome Scale (Kay et al., 1987) was administered to the patients (positive subscale=14.0, SD=6.9; negative subscale=10.8, SD=3.0; general subscale=24.9, SD=6.8). Healthy controls were recruited from the local community. They were screened for the absence of Axis I psychiatric disorders using a standardized interview based on the SCID-I/NP (First et al., 2002). The two groups of subjects were matched in terms of average age and gender composition.

The Wechsler Adult Intelligence Scale – Revised (verbal component) (Wechsler, 1981) was administered to all participants. The participants had normal or corrected to normal vision, as assessed by the Rosenbaum Pocket Vision Screener. Table 1 provides demographic information of the participants.

2.2. Procedures

Visual stimuli were photograph images of face or car, alone or with uniform visual noise superimposed. A series of additional face and car images were created by morphing between two original photographed faces (from two different individuals) or between two original photographed cars (from two different models) (Fig. 1). Morphing was implemented using FantaMorphPro (v5.0, 2012), which automatically detects visually salient points of two original images and generates new images with points transitioning from one original set to another. As such, the resultant images contained varying proportions of two original items. Paired images for comparison had five levels of differences in the proportion of two original items: 5%, 12.5%, 25%, 50%, 100%, generating five levels of signal strength for face or car identity comparison. For example, to achieve a 5% difference between two face identities, the two original face images would be morphed to create two images: one containing 47.5% of one identity and 52.5% of the other identity, and the other containing 52.5% of one identity and 47.5% of the other identity.

The noise was created by randomly selecting a half of the pixels across an image and assigning them a fixed luminance rather than the values defined by the image itself. These noise pixels were randomly but evenly distributed across space. A single level of uniform noise was added to the images, both the original ones and morphed versions of the original ones (Fig. 1).

Two types of visual discrimination tasks, one for faces and the other for cars, were used. The task was to discriminate between a series of paired face or car images, based upon their identities. Each trial included two sequential presentations with a 500 ms pause in between. The brief inter-stimulus interval ensured that patients' perceptual performance was evaluated independently of working memory constraints (Chen et al., 2009; Park and Holzman, 1992). The first presentation contained a single image (600 ms). The second presentation contained a pair of images side by side (1200 ms), one of which was identical to that in the first presentation, and the other of which differed to varying degrees. Subjects determined which of the two images in the second presentation was the same as the image in the first presentation. This two alternative force choice procedure was administered with and without the presence of noise. Four testing sessions were blocked according to image type (face or car) as well as noise status (presence or absence). The order of presentation of the four task conditions was counterbalanced across subjects. With five levels of identity comparisons, each repeated 8 times, all sessions contained 40 trials. The order of the trials in a testing block was randomized across 5 stimulus strengths within each trial. The percent of correct trials or accuracy was used as a primary measure of perceptual performance.

All stimuli and task procedures were programmed within VisionShell on a G3 Mac computer, which also recorded subjects' responses. Subjects received a general training which included instructions and practice time for each task prior to formal data collection. During the practice, four types of trials (regular face images, noisy face images, regular car images and noisy car images) were presented and were repeated if asked by a subject. The study protocol was approved by the Institutional Review Board of McLean Hospital, and written informed consent was obtained from all participants.

3. Results

Table 2 summarizes the performance accuracies and the perceptual thresholds of face discrimination and car discrimination for patients and controls.

Table 1
Demographic characteristics of the sample: group mean (standard deviation).

	Sex	Age (year)	Verbal IQ*	Education (year)	Parental education (year)
Controls (n=27)	13-M, 14-F	43.0 (15.2)	111.5 (12.7)	15.3 (1.8)	14.7 (3.7)
Patients (n=25)	15-M, 10-F	43.3 (9.6)	101.4 (11.4)	14.0 (2.1)	14.4 (3.0)

F – female; M – male.
* Statistically significant ($p < 0.05$).

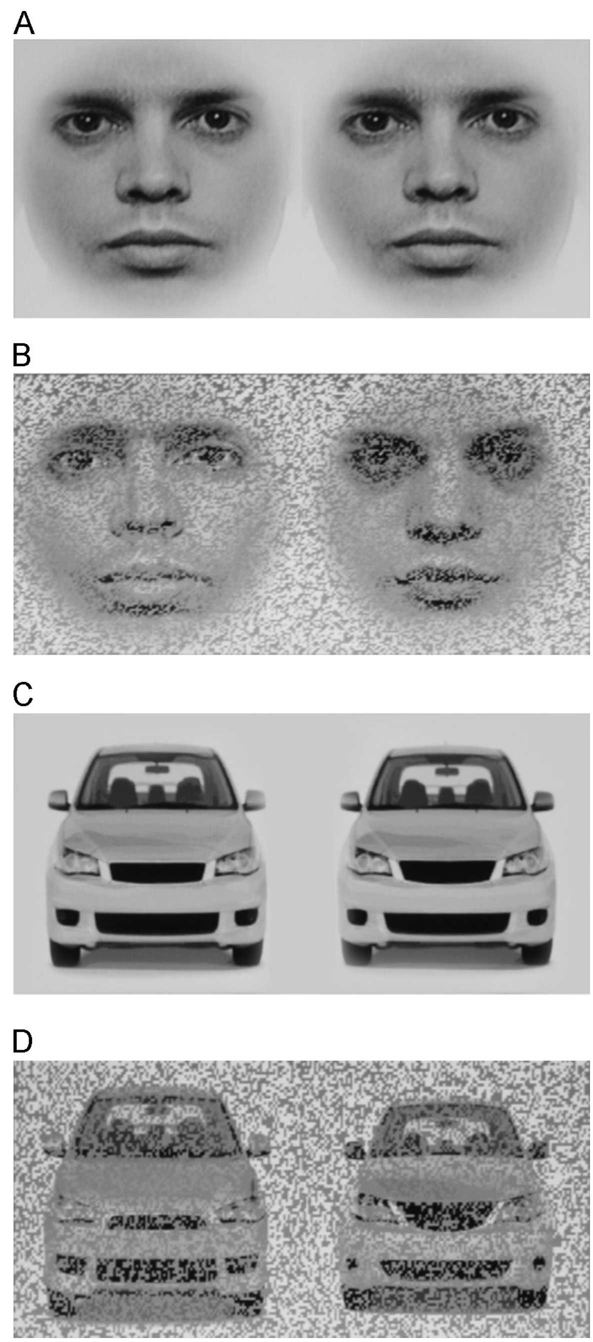

Fig. 1. Schematic illustration of face and car stimuli used in this study. Panels A and C show a pair of comparison original faces and original cars under the no-noise condition, respectively, whereas panels B and D show a pair of comparison original faces and original cars under the noise condition, respectively.