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Research report

Acquired prosopagnosia abolishes the face inversion effect

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ABSTRACT

Individual faces are notoriously difficult to recognize when they are presented upside-down. Since acquired prosopagnosia (AP) has been associated with an impairment of expert face processes, a reduced or abolished face inversion effect (FIE) is expected in AP. However, previous studies have incongruently reported apparent normal effects of inversion, a decreased or abolished FIE, but also a surprisingly better performance for inverted faces for some patients. While these discrepant observations may be due to the variability of high-level processes impaired, a careful look at the literature rather suggests that the pattern of FIE in prosopagnosia has been obscured by a selection of patients with associated low-level defects and general visual recognition impairments, as well as trade-offs between accuracy and correct RT measures. Here we conducted an extensive investigation of upright and inverted face processing in a well-characterized case of face-selective AP, PS (Rossion et al., 2003). In 4 individual face discrimination experiments, PS did not present any inversion effect at all, taking into account all dependent measures of performance. However, she showed a small inversion cost for individualizing members of a category of non-face objects (cars), just like normal observers. A fifth experiment with personally familiar faces to recognize confirmed the lack of inversion effect for PS. Following the present report and a survey of the literature, we conclude that the FIE is generally absent, or at least clearly reduced following AP. We also suggest that the paradoxical superior performance for inverted faces observed in rare cases may be due to additional upper visual field defects rather than to high-level competing visual processes. These observations are entirely compatible with the view that AP is associated with a disruption of a process that is also abolished following inversion: the holistic representation of individual exemplars of the face class.

1. Introduction

Individual faces are notoriously difficult to discriminate and recognize when they are presented upside-down (e.g., >Hochberg and Galper, 1967; Yin, 1969). This phenomenon has been known for decades and has generated tens or perhaps hundreds of studies in cognitive (neuro)science comparing behavioral performance and/or neural responses to upright and inverted face stimuli. While researchers still debate the cause(s) of this face inversion effect (FIE), most if not all authors in the field would acknowledge that inversion disrupts fundamental processes underlying our expertise at

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processing faces. Understanding the nature of the FIE is thus a major challenge for researchers in this field (Rossion, 2008).

Another potential way to understand the nature of face processes through their disruption is by studying the behavior of brain-damaged patients who can no longer recognize individual faces, i.e., acquired prosopagnosia (AP). Prosopagnosia is classically defined as the inability to recognize individual faces following brain damage, an impairment which cannot be attributed to intellectual deficiencies or low-level visual problems (Quaglino and Borelli, 1867; Bodamer, 1947; Rondot and Tzavaras, 1969). The nature of the face processing impairment in prosopagnosia has also been debated in the literature for decades (e.g., Rondot and Tzavaras, 1969; Damasio et al., 1982; Sergent and Signoret, 1992). While some authors have emphasized the variety of functional deficits among patients (Sergent and Signoret, 1992; Schweich and Bruyer, 1993), there are striking similarities among many cases of prosopagnosia, even when the localization of their brain lesions differs greatly. In many reports, AP has been associated with a deficit in holistic/configural face processing, i.e., a defect at integrating simultaneously the multiple features of a face into a single global perceptual representation (e.g., Galli, 1964; Levine and Calvanio, 1989; Sergent and Villemure, 1989; Sergent and Signoret, 1992; Saumier et al., 2001; Boutsen and Humphreys, 2002). More recently, it has also been found that prosopagnosic patients have particular difficulties at extracting diagnostic information from the eyes (Caldara et al., 2005; Bukach et al., 2006), a region of the face that is made of multiple elements, or at perceiving relative distances between features (Barton et al., 2002). These two aspects of prosopagnosia may also be related to a loss of holistic face processing (Rossion, 2008).

How do AP patients process upright and inverted faces? In principle, clarifying this relationship between prosopagnosia and inversion is potentially important because it could shed light on both the nature of face inversion and prosopagnosia, in particular reinforcing or questioning the view that the (in)ability to process individual faces holistically is at the heart of the AP syndrome.

If the outcome of brain damage on putative expert face processes is as detrimental as inverting the face stimulus for normal observers, so to speak, one would expect that AP patients do not show a normal FIE: it should be seriously reduced or even abolished. However, even when considering only the experiments performed with whole upright and inverted faces in individual discrimination/recognition tasks, four different outcomes have been observed: (1) an *absence of inversion cost* in several cases (McNeil and Warrington, 1991, case 2 in accuracy and RTs; Boutsen and Humphreys, 2002, patient HJA in accuracy; Delvenne et al., 2004, patient NS in accuracy and RTs); (2) a *reduced FIE* in two cases tested with manipulations of local and relational cues for individualizing faces (Barton et al., 2003, patient TS in accuracy; Bukach et al., 2006, patient LR in accuracy); (3) a *normal effect* in one patient (Anaki et al., 2007, patient DBO in accuracy and RTs); and (4) a *reverted inversion effect*, namely a better performance for inverted faces in some cases (Farah et al., 1995a, 1995b; de Gelder and Rouw, 2000a, 2000b, patient LH in accuracy and RTs; de Gelder et al., 1998, patient AD in accuracy). In addition, there are ambiguous cases (e.g., Riddoch et al., 2008, patient FB, reverted trend in RTs for same responses, but normal effect with different responses) and inconsistencies in the results reported for the same patients in the literature. For example, the (prosop)agnosic patients CR, SM and RN were tested in several studies (Gauthier et al., 1999; Marotta et al., 2002; Behrmann et al., 2005). Gauthier et al. (1999) reported large inversion effects in both accuracy and RTs for CR and SM. In another study (Marotta et al., 2002), CR still performed better with upright faces, but was significantly faster for inverted faces, contrary to controls, suggesting a speed-accuracy trade-off. In that study, the patient RN did not show any effect in accuracy but a normal inversion effect in RTs (Marotta et al., 2002). However, most recently, all three patients, considered as a group, were reported as performing slightly better and faster with inverted faces (Behrmann et al., 2005).

Thus, overall, the outcome of inversion on individual face processing in AP remains unclear. One way to account for the variability across patients is by acknowledging the great variability in terms of functional impairments of AP, following different lesion localization(s) and aetiologies, as well as putative compensatory strategies (Sergent and Signoret, 1992; Schweich and Bruyer, 1993). However, when considering the literature on face inversion and prosopagnosia attentively, one cannot help noting a number of methodological issues in patient selection, tasks performed, variables measured and analyzed, as well as possible overinterpretations of some observations. As a result, the variety of outcomes reported about inversion effects in prosopagnosia may equally well have been created by the different kinds of experiments performed rather than reflecting a true functional variability in terms of *face* processes. This argument is supported by several observations. First, as noted above, there are inconsistencies in the results reported for the same patients in the literature (e.g., Gauthier et al., 1999; Marotta et al., 2002; Behrmann et al., 2005). These opposite patterns across studies, observed during individual face matching tasks in the same brain-damaged patients, cast doubts on the conclusions that can be drawn from these studies at least regarding the FIE in prosopagnosia. It is worth noting also that these cases were close to chance level with upright faces in several experiments, making difficult to draw clear conclusions. Second, many studies do not measure or report correct RTs during individual face processing tasks (e.g., de Gelder et al., 1998; de Gelder and Rouw, 2000a, 2000b; Boutsen and Humphreys, 2002). Yet, it is known that when having to match/discriminate individual faces, prosopagnosic patients can achieve reasonably high scores by using unnatural (i.e., analytical) strategies (Davidoff and Landis, 1990; Farah, 1990), which may be revealed by abnormally long RTs. Moreover, correct RTs are a highly sensitive measure of the effects of face inversion in normal observers (see Rossion, 2008). Most importantly, when RTs are measured in studies of face inversion in prosopagnosia, they are rarely considered with respect to accuracy to rule out potential speed-accuracy trade-offs effects (e.g., Marotta et al., 2002), or combined with accuracy to obtain a global face inversion index. Third, most studies do not compare the processing of upright and inverted faces to non-face objects presented at the two orientations (McNeil and Warrington, 1991; Farah et al., 1995a, 1995b; Marotta et al., 2002; Delvenne et al., 2004;