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The horizontal and vertical relations in upright faces are transmitted by different spatial frequency ranges

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Abstract

Faces convey distinct types of information: features and their spatial relations, which are differentially vulnerable to inversion. While inversion largely disrupts the processing of vertical spatial relations (e.g. eyes' height), its effect is moderate for horizontal relations (e.g. interocular distance) and local feature properties. The SF ranges optimally transmitting horizontal and vertical face relations were here investigated to further address their functional role in face perception. Participants matched upright and inverted pairs of faces that differed at the level of local featural properties, horizontal relations in vertical relations. Irrespective of SF, the inversion effect was larger for vertical than horizontal and featural cues. Most interestingly, SF differentially influenced the processing of vertical, horizontal and featural cues in upright faces. Vertical relations were optimally processed in intermediate SF, which are known to carry useful information for face individuation. In contrast, horizontal relations were best conveyed by high SF, which are involved in the processing of local face properties. These findings not only confirm that horizontal and vertical relations play distinct functional roles in face perception, but they also further suggest a unique role of vertical relations in face individuation.

PsycINFO classification: 2323

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1. Introduction

The question of how humans encode, store and recognize hundreds of individuals based solely on facial information has impelled decades of research in high-level vision and is still being investigated (Farah, Wilson, Drain, & Tanaka, 1998; Sinha, Balas, Ostrovsky, & Russell, 2006). Each face conveys a multitude of information both at the local level of its constituent features (eyes, nose, etc.) and at the level of the spatial relations organizing such features (e.g. the relative distance between nose and mouth, or between eyes and nose, or between mouth and chin, etc.).

In 1969, Yin (1969) made the intriguing observation that picture-plane inversion dramatically impairs face processing skills. This inversion effect (IE) is larger for faces than for most other visual stimuli (McKone, Kanwisher, & Duchaine, 2007; see Reed, Stone, Bozova, & Tanaka, 2003). Consequently, inversion has been largely used as a tool to disrupt face-specialized processes (e.g. Rhodes, Peters, Lee, Morrone, & Burr, 2005). However, there is evidence demonstrating that inversion does not affect all aspects of face information equally. In upright faces, humans are able to process both the features and their spatial relations. But, once faces are inverted, human sensitivity declines more for spatial relations than for local feature properties (Bartlett & Searcy, 1993; Freire, Lee, & Symons,

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2000; Leder & Bruce, 2000). These findings indicate that features and their spatial relations are dissociable cues for face perception. Some authors have also suggested that face individuation skills for upright faces rely on the processing of spatial relations (e.g. Maurer, Grand, & Mondloch, 2002).

Multiple spatial relations define each individual face (Farkas, 1994; Shi, Samal, & Marx, 2006). In most face perception studies, it is implicitly assumed that all these spatial relations equally contribute to face perception and, hence, are equally affected by inversion. However, our recent investigations contradict this view (Goffaux & Rossion, 2007). We showed that when faces were inverted, sensitivity to vertical spatial relations decreased (for example, eyes or mouth height; see also Barton, Keenan, & Bass, 2001), whereas the perception of horizontal relations and local feature properties remains comparably accurate. This finding could not be attributed to differential difficulty with regard to processing vertical as opposed to horizontal spatial relations as matching performance across these conditions was equivalent for upright faces. Furthermore, the dissociable effects of inversion could not be accounted for by the fact that inversion and vertical relational manipulation both alter vertical face organization. The largest detriments were indeed invariably observed for vertical relations at other rotation angles (Goffaux & Rossion, 2007, experiment 3).

These findings helped resolving empirical discrepancies across past studies on face inversion, which confounded horizontal and vertical relational manipulation (e.g. Riesenhuber, Jarudi, Gilad, & Sinha, 2004; Yovel & Kanwisher, 2004) and highlighted crucial dimensions of face information. The differential vulnerability of vertical and horizontal relations to inversion reflects their distinct functional contribution to face perception. Nevertheless, the reasons of the selective vertical IE remain to be clarified.

As inversion is accompanied by substantially inferior face identification than observable for upright faces, the large IE observed for vertical relations suggests their predominant role for upright face processing skills. In contrast, the weak IE observed for horizontal relations suggests that these are processed at a local scale and do not contribute to the efficient upright individuation skills. However, it is not clear how vertical relations contribute to upright face perception. On the one hand, since faces are vertically elongated shapes, feature integration in upright faces may crucially rely on vertical relations. On the other hand, the vertical IE may indicate a more fundamental role of vertical relations in face processing. The face processing system may be tuned to process vertical relations because these could be the most useful/discriminative when individuating faces.

It was the aim of the present experiment to further explore the respective contribution of vertical and horizontal relations in face perception. We addressed whether the processing of these two types of cues rely on different input spatial frequencies (SF). The extraction of SF is a primary step in early vision (see De Valois & De Valois, 1988; Sowden & Schyns, 2006 for a recent review). Interestingly, the high-level processing of faces is also largely influenced by input SF. This SF reliance is thought to be larger for faces than for other visual categories (Biederman & Kalocsai, 1997; Boutet, Collin, & Faubert, 2003; Collin, Liu, Troje, McMullen, & Chaudhuri, 2004; Liu, Collin, Rainville, & Chaudhuri, 2000). Various aspects of face information have indeed been found to map onto distinct SF ranges. For example, judging the gender of a face relies on lower SF than judging its emotional expressivity (e.g. Schyns, Bonnar, & Gosselin, 2002). In contrast, a 2-octave-wide range of SF situated between 8 and 16 cpf is known to convey inter-individual face differences most efficiently. Intermediate spatial frequency (ISF; ca. 12cpf, e.g. Näsänen, 1999) input thus optimally promotes recognition of familiar faces. In contrast, low spatial frequencies (LSF, below 8 cycles per face or cpf) contain much poorer information and govern the fast integration of face features into a united representation (Goffaux, Hault, Michel, Vuong, & Rossion, 2005; Goffaux & Rossion, 2006; see Sergent, 1986). Lastly, high spatial frequency (HSF, above 32 cpf) information transmits the local details of face features.

In the present paper, we took advantage of the fact that various SF subserve different goals in face perception by identifying which SF ranges optimally convey vertical and horizontal relational information. As the differential IE observed for horizontal and vertical relations indicates their dissociable contribution to face perception, it is plausible that these cues are represented by different SF ranges. Defining these ranges will in turn clarify their role in face perception.

Participants discriminated upright and inverted pairs of faces that varied either at the level of a given local feature (eye shape and surface), or with respect to vertical or horizontal relations (eyes positioned higher/lower or closer/further apart, respectively). Stimuli were filtered to exclusively preserve LSF, ISF or HSF. We used two measures to probe featural, horizontal and vertical processes across SF: upright performance and IE magnitude (upright minus inverted performance). For upright faces, we expected horizontal and vertical processing to rely on different SF ranges. Our hypothesis was that if vertical relations are more significant than horizontal relations to individuate upright faces, they should be best conveyed by ISF. Alternatively, vertical relations may be more crucial for upright faces than horizontal ones simply because features are integrated more intensely along than across the vertical elongation axis. In this case, they should be best processed in LSF. In contrast, since horizontal and featural cues are spared by inversion, we expected them to be processed locally and to rely on higher SF than vertical relations. Moreover, by selectively targeting vertical relations, we expected to observe larger IE in the SF ranges best conveying vertical relations for upright faces.