Cognition 158 (2017) 33–43

Contents lists available at ScienceDirect

Cognition

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

Original Articles

From face processing to face recognition: Comparing three different processing levels

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ARTICLE INFO

Article history:
Received 12 February 2016
Revised 26 September 2016
Accepted 6 October 2016
Available online 21 October 2016

Keywords:
Face recognition
Face categorization
Face detection
Familiarity
Reaction times
Inversion effect

ABSTRACT

Verifying that a face is from a target person (e.g. finding someone in the crowd) is a critical ability of the human face processing system. Yet how fast this can be performed is unknown. The 'entry-level shift due to expertise' hypothesis suggests that - since humans are face experts - processing faces should be as fast – or even faster – at the individual than at superordinate levels. In contrast, the 'superordinate advantage' hypothesis suggests that faces are processed from coarse to fine, so that the opposite pattern should be observed. To clarify this debate, three different face processing levels were compared: (1) a superordinate face categorization level (i.e. detecting human faces among animal faces), (2) a face familiarity level (i.e. recognizing famous faces among unfamiliar ones) and (3) verifying that a face is from a target person, our condition of interest. The minimal speed at which faces can be categorized (~260 ms) or recognized as familiar (~360 ms) has largely been documented in previous studies, and thus provides boundaries to compare our condition of interest to. Twenty-seven participants were included. The recent Speed and Accuracy Boosting procedure paradigm (SAB) was used since it constrains participants to use their fastest strategy. Stimuli were presented either upright or inverted. Results revealed that verifying that a face is from a target person (minimal RT at ~260 ms) was remarkably fast but longer than the face categorization level (~240 ms) and was more sensitive to face inversion. In contrast, it was much faster than recognizing a face as familiar (~380 ms), a level severely affected by face inversion. Face recognition corresponding to finding a specific person in a crowd thus appears achievable in only a quarter of a second. In favor of the 'superordinate advantage' hypothesis or coarse-to-fine account of the face visual hierarchy, these results suggest a graded engagement of the face processing system across processing levels as reflected by the face inversion effects. Furthermore, they underline how verifying that a face is from a target person and detecting a face as familiar – both often referred to as "Face Recognition" – in fact differs.

1. Introduction

Individuals are mostly recognized by their faces. Something we do daily for example is *verifying that a face is from a target person* (e.g. finding someone in the crowd). Classically, it is investigated in experimental tasks by proposing a verbal label to participants (e.g. "Brad Pitt") and asking them whether subsequently presented faces match or not with the label.

Objects are usually categorized faster at the basic-level (e.g. bird vs. other animals) than at the superordinate (e.g. animal vs. vehicle) or subordinate-level (e.g. Indigo Bunting vs. other birds)

Abbreviations: RT, Reaction Time; minRT, minimal RT; HFC, Human Face Categorization; IFR, Individual Face Recognition; FFR, Familiar Face Recognition; SAB, Speed and Accuracy Boosting procedure.

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http://dx.doi.org/10.1016/j.cognition.2016.10.004
0010-0277/

(Rosch et al., 1976). The basic level is thus thought to be the entry level at which people first process objects (Anaki & Bentin, 2009; Johnson & Mervis, 1997; Jolicoeur, Gluck, & Kosslyn, 1984; Rosch et al., 1976; Tanaka, 2001; Tanaka & Taylor, 1991; Wong & Gauthier, 2007). However, this entry level may shift to the subordinate level with atypicality (e.g. penguins categorized faster than as birds; Jolicoeur et al., 1984) or with expertise (e.g. Indigo Bunting categorized as fast as birds by expert bird watchers; Johnson & Mervis, 1997; Tanaka & Taylor, 1991). Humans are usually considered to be face experts (Carey & Diamond, 1977; Carey, Schonen, & Ellis, 1992; Tanaka & Gauthier, 1997). Consistent with this idea, it has been shown that faces are categorized as fast - or even faster (see Anaki & Bentin, 2009) - at the individual level (e.g., as Brad Pitt) than at a superordinate level (e.g., as a human face) (Anaki & Bentin, 2009; Tanaka, 2001).

However, at odds with such interpretation, neurophysiological or neuroimaging studies have suggested that superordinate, coarse, information is processed before the more detailed information required for higher-level categorization (Large, Kiss, & McMullen, 2004; Löw et al., 2003; Martinovic, Gruber, & Müller, 2008; Sugase, Yamane, Ueno, & Kawano, 1999; for faces, see Goffaux et al., 2011). Interestingly, behavioral tasks also argue in favor of such a *coarse-to-fine access* to perceptual representations (Fabre-Thorpe, 2011; Hochstein & Ahissar, 2002), when studying *minimal reaction times* (minRT) - i.e. the minimal processing time necessary to give reliable responses (Rousselet, Macé, & Fabre-Thorpe, 2003). Aforementioned behavioral studies indeed classically studied mean or median RTs without speed constraints. However, these RTs could reflect processes which are not strictly necessary, such as verification or access to lexical information. For example, access to basic words could be shorter than access to superordinate words since they are more frequently used. Using the minRT approach, Macé, Joubert, Nespoulous, and Fabre-Thorpe (2009) showed a *superordinate advantage* compared to the basic level when animals had to be categorized, a finding further confirmed in other studies (Kadar & Ben-Shahar, 2012; Loschky & Larson, 2010; Praβ, Grimsen, König, & Fahle, 2013; Vanmarcke & Wagemans, 2015; Vanmarcke et al., 2016). Such superordinate-level advantage was shown to be independent of stimuli duration or target and distractor diversity (Poncet & Fabre-Thorpe, 2014).

The prediction of the superordinate advantage level hypothesis for faces would be that faces would be categorized faster at the superordinate than at the individual level, despite the expertise advantage. To date, only one study compared different levels of face categorization using minimal RTs. In this study, participants had to perform a 'human face vs. animal face' superordinate categorization task, which was contrasted with a 'familiar face vs. unfamiliar face' subordinate recognition task. Results were clear as the superordinate task was performed much faster (minRT: ~250 ms) than the subordinate (~440 ms) (Barragan-Jason, Lachat, & Barbeau, 2012). Although particularly strong, such an effect was expected since the superordinate categorization task can rely on the detection of low-level features (Crouzet, Kirchner, & Thorpe, 2010; Rossion & Caharel, 2011; Rossion & Jacques, 2011) and hence be very fast (about 260 ms, reviewed in Fabre-Thorpe, 2011). In contrast, participants had to recognize famous faces among unknown ones in the subordinate (i.e. familiarity) task. They did not know in advance which famous faces would be presented. Each face thus had to be processed up to the individual level in a bottom-up fashion before a familiarity signal could be triggered. Such level of processing thus refers to a particular kind of face recognition task, for which no clue is available before the face is processed, and more akin to unexpectedly meeting an acquaintance in the street (Fig. 1A). Several studies have now reported that such face recognition task can be performed at about 360 ms at the fastest (Barragan-Jason, Besson, Ceccaldi, & Barbeau, 2013; Barragan-Jason et al., 2012; Besson, Ceccaldi, Didic, & Barbeau, 2012), a quite long delay compared to face categorization tasks.

What about verifying that a face is from a target person, the other face processing level aforementioned (Fig. 1A)? Such task has never been studied using a minimal RT approach. Under the entry level shift due to expertise hypothesis, such task should be performed faster – or at least as fast – than a superordinate level task (Anaki & Bentin, 2009; Tanaka, 2001). Under the superordinate advantage level hypothesis in contrast, such task should need more processing time than a superordinate task. In fact, some studies have reported strikingly fast RTs (about 250 ms) in similar tasks, suggesting it is worth investigating this issue in detail (Lewis & Ellis, 2000).

How fast verifying that a face is from a target person would be relatively to detecting a face as familiar when no clue is available also remains unclear. In fact, the numerous terms used to refer to the verification that a face is from a target person ('category-verification task', Tanaka, 2001; 'individual-level verification task', Anaki & Bentin, 2009; or 'face-identification task', e.g. Delorme & Thorpe, 2001; Reddy, Reddy, & Koch, 2006) highlights how much its underlying mechanisms remain poorly understood. Specifically, does such a task need to rely on a *person identity-level* - a higher, amodal and semantic level of representation, which would follow visual processes (Bruce & Young, 1986)? If so, verifying a face identity would be best described as a 'face-identification task' and would be rather long, for instance close to familiarity tasks (Valentine, 2001). In contrast, verifying a face identity could rely on facial diagnostic clues (e.g. specific facial features characteristic of a face) that could help preparing and optimizing visual processing through top-down strategies, such as preactivation and attentional selection (e.g. Eimer, 2014). In this case, it could be quite fast, and close to categorization tasks, which rely on similar mechanisms.

In this study, we compared performance speed in an Individual Face Recognition task (i.e. verifying that a face is from a target person) to a Human Face Categorization task and to a Familiar Face Recognition task. The difference between these conditions is visually schematized in Fig. 1A. Interestingly, the distinction between Individual Face Recognition and Familiar Face Recognition conditions is not always clear in the literature whereas they may rely on different processes and hence yield different RTs.

As already presented, the speed at which faces can be processed is largely known for either Human Face Categorization (minRT: ~260 ms) or Familiar Face Recognition (minRT: ~360 ms). The aim of this study is to assess the speed of Individual Face Recognition compared to these boundaries (Fig. 1B), and thus to determine what temporal hierarchy, if any, there is between these three levels of face processing. To test the entry level shift related to expertise or the superordinate level hypotheses, we will compare minimal RTs in the Individual Face Recognition condition to the Human Face Categorization and Familiar Face Recognition conditions (Fig. 1C). For such comparisons to make sense, it is necessary to constrain participants to use their fastest strategy in each condition (Barragan-Jason et al., 2013). We thus used the Speed and Accuracy Boosting procedure (SAB), a recent procedure based on a go/no-go paradigm with a response deadline (Besson et al., 2012) in which responses must be provided before a constraining time limit, set in this study at 600 ms (Fig. 1D). Last, since face inversion is known to disrupt holistic processing and access to face configuration, we investigated the effect of face inversion on these different conditions, by also running all three with inverted stimuli (Farah, Wilson, Drain, & Tanaka, 1998; Maurer, Grand, & Mondloch, 2002; Rossion, 2008; Yin, 1969).