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Behavioral and electrophysiological evidence for configural processing in fingerprint experts

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Abstract

Visual expertise in fingerprint examiners was addressed in one behavioral and one electrophysiological experiment. In an X-AB matching task with fingerprint fragments, experts demonstrated better overall performance, immunity to longer delays, and evidence of configural processing when fragments were presented in noise. Novices were affected by longer delays and showed no evidence of configural processing. In Experiment 2, upright and inverted faces and fingerprints were shown to experts and novices. The N170 EEG component was reliably delayed over the right parietal/temporal regions when faces were inverted, replicating an effect that in the literature has been interpreted as a signature of configural processing. The inverted fingerprints showed a similar delay of the N170 over the right parietal/temporal region, but only in experts, providing converging evidence for configural processing when experts view fingerprints. Together the results of both experiments point to the role configural processing in the development of visual expertise, possibly supported by idiosyncratic relational information among fingerprint features.

Keywords: Fingerprints; Faces; Configural; N170; Expertise; Inversion

1. Introduction

The training and exposure that fingerprint examiners undergo as part of their profession represents an extreme case of perceptual learning. These experts receive extensive training in the fingerprint identification process with competency testing under an accomplished professional. In addition, the penalty for incorrect identifications is quite high: lives or careers could be ruined and labs shut down because of inappropriate accusations or exonerations. As a result, fingerprint examiners take their jobs very seriously and spend a great deal of time studying prints. This situation produces an intensive study of a stimulus set that may lead to profound changes to the perceptual systems of fingerprint examiners. Given this pool of expertise, it is somewhat surprising to find that very few if any empirical studies have addressed how long-term exposure to fingerprints might alter the perceptual processing of latent and inked prints by examiners. The goal of this article is to characterize the differences between fingerprint experts and novices, and address the nature of the strategies and visual skills that experts may have developed during training. The results not only bear on the nature of skill development with examiners, but help constrain models of perceptual learning as well, in particular the role and nature of configural processing in visual expertise.

While relatively little work has been done with fingerprint examiners, we draw upon several related studies of expertise that have identified behavioral and neural correlates of expertise (e.g. Gauthier, Skudlarski, Gore, & Anderson, 2000; Rossion, Gauthier, Goffaux, Tarr, & Crommelinck, 2002; Shiffrin & Lightfoot, 1997; Tanaka & Curran, 2001), since fingerprints share some

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characteristics with faces and other stimuli that exhibit perceptual learning. Goldstone (1998) identified four general mechanisms that might support the development of perceptual expertise. For stimuli that can be represented along different psychological dimensions, attention weighting allows more emphasis to be placed on relevant dimensions, and differentiation allows increased separation between objects in psychological space. In addition to these manipulations of dimensional representations, new features can be created, either through imprinting, which creates new receptors specific to the to-be-learned features (Schyns & Murphy, 1994; Schyns & Rodet, 1997), or unitization, which creates complex configurations out of single features (Shiffrin & Lightfoot, 1997). For more naturalistic stimuli without clear psychological dimensions, much of the emphasis of expertise research has addressed the role of relational information and context-related effect in which the perception of one feature is influenced by the presence or absence of other features. Both of the mechanisms can be subsumed under the general category of configural processing. Configural effects have long been studied in faces (Yin, 1969), and more recently these effects have been extended to other types of objects. Perhaps the most comprehensive look at training effects with novel stimuli is work with Greeble stimuli by Gauthier and Tarr (1997) and Gauthier, Williams, Tarr, and Tanaka (1998), who described configural benefits for single features when surrounded by the appropriate context, but only after training and only for upright stimuli. Later work has suggested that this form of configural processing is supported by the gradual development of relational information between features throughout the course of learning (Gauthier & Tarr, 2002).

The neural basis for expertise has been addressed in imaging experiments (Gauthier et al., 2000; Gauthier, Tarr, Anderson, Skudlarski, & Gore, 1999; Tarr & Gauthier, 2000), electrophysiological studies (Gauthier, Curran, Curby, & Collins, 2003; Rossion, Gauthier, et al., 2002; Tanaka & Curran, 2001) and single-cell recording (Baker, Behrmann, & Olson, 2002; Logothetis, 2000). It appears that brain regions that initially are highly responsive to complex visual objects such as faces are also activated by learned stimuli after training, suggesting a recruitment of face-responsive areas to support expertise for other complex objects (although see Carmel & Bentin (2002) for a defense of a modular account of face processing). At the level of single cells, configural processing seems to occur via increasing specialization of responses to conjunction stimuli, rather than increased firing rates (Baker et al., 2002).

Fingerprint matching shares some similarity with a radiological screening process, and several articles have documented expertise effects with radiologists. Sowden, Davies, and Roling (2000) found that experts could better detect low-contrast dots embedded in simulated X-rays, and Myles-Worsley, Johnston, and Simons (1988) reported that experts had better memory performance for abnormal X-rays while exhibiting worse performance for normal X-rays.

Fingerprint examinations are somewhat unique as a task. Unlike tumor detection, which is essentially a categorization task, latent fingerprints are compared with a very specific candidate sample. While this task shares some of the characteristics of an identification process, both samples are present simultaneously. In addition, fingerprints share a very small set of features, some of which, such as ridge endings and bifurcations, are distributed in fairly random locations from one print to another. This makes relational information important. However, unlike faces, the feature locations are much less constrained on a fingerprint, and relatively little work has been done with analogous stimuli in the literature. Thus it remains to be seen whether configural processes can develop for fingerprints. If so, this will suggest the conditions under which configural processing can develop.

Given that relatively little literature exists on fingerprint examiners, our first aim is to identify whether experts do indeed differ from novices on tasks related to fingerprint examinations, and then determine whether performance differences might be tied to the mechanisms that have been identified that support perceptual learning. The results of our first experiment will point to the suggestion of configural processing in experts, and we follow this up with a second experiment designed to look for neurophysiological evidence of configural processing.

2. Experiment 1

Although some elements of initial triage and screening might be handled via a computer, virtually all evidence presented in court is based on a visual match made by an examiner. Fingerprints contain characteristic features such as general ridge paths of loop, whorl, or arch, as well as idiosyncratic features of specific ridge paths with ridge endings or bifurcations, and texture and pore positions on ridges. This provides a very consistent visual diet for examiners, which may enable their visual system to adopt strategies that enhance information acquisition from one fingerprint. The training may also enhance maintenance of visual information during an eyemovement, and thus Experiment 1 includes an element of visual working memory.

Fingerprints are somewhat like faces in that they have certain features that tend to occur in similar locations across exemplars, and thus may exhibit properties in experts similar to those seen with faces, most notably configural processing and superior subordinate-level categorization performance (e.g. Tanaka, 2001). Thus