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Hometown size affects the processing of naturalistic face variability

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ABSTRACT

Face exposure during development determines adults' abilities to recognize faces and the information they use to process them. Individual differences in the face categories represented in the visual environment can lead to category-specific deficits for recognizing faces that are atypical of observer's experience (e.g. the other-race effect). But what happens when observers have limited opportunities to learn about faces in general? In previous work, we found that observers from depopulated areas have poorer face recognition performance than observers from larger communities, suggesting that impoverished face experience limits face processing broadly. Here, we further investigate this phenomenon by examining how hometown size impacts the ability to assess appearance variability in natural images of faces and bodies. We asked individuals from small and large communities to complete (1) an unconstrained card-sorting task designed to test observers' ability to categorize within-person and between-person appearance variability properly, and (2) the Cambridge Face Memory Test. For both tasks, we examined the direct comparison between groups as well as the relationship between CFMT scores and sorting performance as a function of face experience. We find that small-town observers perform more poorly on the CFMT, but exhibit both better and worse performance than large-town observers on different aspects of the card-sorting task. Further, we also examine the relationship between CFMT performance and card-sorting errors. Our results suggest that individual differences in lifetime face exposure induce important variation in face processing abilities.

1. Introduction

Individual differences in observers' visual experience with faces lead to variation in their ability to recognize them. Perhaps the most profound example of this comes from multiple studies describing the various deficits in face processing that observers who were born with congenital cataracts experience even years after their cataracts have been removed. Typically, these participants have had their cataracts treated relatively early in infancy, yet in multiple tasks it is evident that their face recognition abilities differ from typical observers. For example, patients treated for bilateral congenital cataracts perform more poorly on the Famous Faces task, the Cambridge Face Memory Test (Duchaine & Nakayama, 2006), and the Benton Facial Recognition Task (Benton, Sivan, Hamsher, Varney, & Spreen, 1983; de Heering, Rossion, & Maurer, 2011), despite self-reporting face recognition skills in the same range as typical observers (de Heering & Maurer, 2014). These assessments involve recognizing ostensibly familiar individuals (the Famous Faces Task), learning to recognize novel faces (the CFMT) and matching identity across changes in view using simultaneously presented images (the Benton Facial Recognition Task). Cataract-reversal patients thus exhibit a number of important deficits that suggest that their disrupted early experience with faces limits their ability to effectively recognize and discriminate individual faces. Besides this evidence that cataract-reversal patients tend to perform less accurately across a range of face recognition tasks, there is also substantial evidence that the way they process faces is also different. Cataract-reversal patients appear to be worse than control participants at discriminating faces that differ according to changes in face geometry (e.g. eye spacing), but perform comparably when faces differ according to the local shape of intuitive facial features like the eyes, nose, and mouth (Le Grand, Mondloch, Maurer, & Brent, 2001; Mondloch, Robbins, & Maurer, 2010). This suggests that the computation of the visual features (whatever they may be) that support the discrimination of faces based on these 2nd-order configural properties (Maurer, Le Grand, & Mondloch, 2002) may be specifically impaired in these patients due to their impoverished early experience. Similarly, cataract-reversal patients also exhibit a reduced Composite Face Effect (Young, Hellawell, & Hay, 1987),

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which has been widely used as a proxy for "holistic" face processing. In the typical CFE, observers are asked to match or discriminate only the top half of face patterns while disregarding the bottom half of the stimulus. Observers tend to find this difficult, ostensibly due to obligatory processing of the entire face pattern which leads to interference from the bottom half of the stimulus even though it is task-irrelevant. If the bottom half of the stimulus is misaligned with the top half, the interference effect is reduced or absent. Unlike control participants, however, cataract-reversal patients do not appear to suffer from such interference (Le Grand, Mondloch, Maurer, & Brent, 2004), which suggests that they may not engage in obligatory holistic processing to the same degree as typical observers. Varying experience with faces thus influences the manner in which faces are processed as well as participants' ability to recognize them effectively. Critically, it is not the case that these patients have a broad visual recognition deficit. Their performance in a number of closely related tasks, including human face detection (Mondloch, Le Grand, & Maurer, 2003) and recognition tasks using other complex patterns (e.g. monkey faces and houses – Robbins, Nishimura, Mondloch, Lewis, & Maurer, 2010), is comparable to controls. This pattern of results indicates a specific relationship between individual differences in face experience and varying face recognition abilities.

True visual deprivation is a fairly extreme example of individual variation in visual experience with faces, and most people do not ever experience such deprivation during their lifetime. Moreover, though cataract-reversal patients do exhibit specific deficits in human face processing, their visual experience has been affected broadly; Pattern vision is broadly compromised prior to treatment. Presently, we chose to examine a subtler form of individual variation in face experience that does not depend on visual deprivation *per se*, but instead is a function of the visual environment: How does face recognition differ as a function of the number of faces you are exposed to? Specifically, does growing up in a sparsely populated area lead to poorer face recognition abilities relative to someone who grew up in a densely populated community? In a previous report (Balas & Saville, 2015), we demonstrated that adult observers who grew up in small communities (populations < 1000) were less accurate than participants from larger communities (populations > 30,000) at learning to recognize new faces, and had weaker face selectivity at the N170 component, which is a known marker of face processing in ERP signals (Rossion & Jacques, 2008). In this study, we characterized participants' ability to learn new faces using the Cambridge Face Memory Test (or CFMT, Duchaine & Nakayama, 2006), which is a standardized face memory assessment that has been widely used to characterize performance in individuals with prosopagnosia. Using the CFMT, we found that the scores of individuals from small-towns were significantly lower ($\sim$10%) than the scores of individuals from large-towns. In terms of the neural responses measured in both groups at the N170 component, we found that while large-town observers had robust differences between face and non-face amplitudes (which is typical of N170 response properties), small-town observers exhibited a smaller amplitude difference between faces and chairs, which suggests poorer category selectivity at this particular component. These results suggest that like biased experience favoring own-race faces over other-race faces (de Heering, de Liedekerke, Deboni, & Rossion, 2010), the overall amount of face exposure observers receive during development affects their ability to recognize faces of all categories effectively.

Presently, we extend this line of work to examine how observers from "small-town" and "large-town" communities process naturalistic variability in images of faces and bodies. Effective person recognition depends critically on being able to tell the difference between image variation that occurs without a change in identity (intra-personal variation) and image variation that does result from a change in identity (extra-personal variation), and explicit modeling of these two sources of variability is the basis of successful computer vision systems for face recognition (Moghaddam, Jebara, & Pentland, 2000) and accounts for some features of infant face learning (Balas, 2012, 2013). Natural images of faces and bodies are highly variable, and while observers are generally able to cope with this high variability when asked to recognize familiar individuals (Bruce, Henderson, Newman, & Burton, 2001), they are generally quite poor when asked to match or discriminate unfamiliar individuals (Bruce et al., 1999, 2001; Johnson & Edmonds, 2009). In particular, a series of results using a simple unconstrained card-sorting task (Jenkins, van White, Montford, & Burton, 2011), reveals key aspects of how observers fail to process intra- and extra-personal variation in images of unfamiliar people. Briefly, when asked to sort a set of images containing multiple instances of an unknown number of individuals based on identity (e.g., estimate the number of unique people in the set), observers tend to substantially overestimate how many different people are being depicted. The pattern of sorting errors suggests that participants are especially poor at "telling faces together" (Andrews, Jenkins, Cursiter, & Burton, 2015), by which we refer to the ability to determine that different images of the same person belong in the same identity group. This tendency is further exacerbated when other-race faces are used (Laurence, Zhou, & Mondloch, 2015), suggesting that one consequence of reduced experience with a set of faces is an increased tendency to "split" identities up when appearance varies. Based on these results, we hypothesized that observers raised in small communities might also have more difficulty "telling faces together" than observers raised in larger communities, as evidenced by increased errors when attempting to categorize intra-personal variation correctly. By including body stimuli in this study, we are also able to comment on several additional issues related to person perception. First, including bodies allows us to examine the generality of card-sorting behavior to a non-face object. Independent of community size, does the sorting bodies exhibit the same patterns of behavior as the sorting of faces? Second, if we are able to observe measurable differences in sorting behavior as a function of community size for faces, do those effects extend to bodies as well? If not, this would suggest that face recognition is uniquely impacted by the variation in experience that is a consequence of hometown size. Alternatively, experience with person recognition (combining face and body expertise) may lead to more general effects of community size on sorting. Finally, there is as yet very little information about how appearance variability is processed in bodies using unconstrained tasks like this, so our inclusion of this condition also provides novel data regarding body processing in naturalistic images.

We recruited adult observers (all college undergraduates) who hailed from both small hometowns and large hometowns to take part in the aforementioned card-sorting task using images of faces and images of bodies. We also asked these participants to complete the Cambridge Face Memory Test, to replicate and extend our prior results regarding observers' ability to learn to recognize new faces as a function of varying face experience during development. We hypothesized that observers with relatively impoverished face experience would perform more poorly on the CFMT, and would be less likely to sort different images depicting the same unfamiliar face into the same identity group during unconstrained sorting. We further conjectured that this effect might not be evident for bodies, if indeed visual experience leads to a specific deficit for face recognition. Finally, we chose to examine the relationship between sorting performance and CFMT performance by investigating the correlations between sorting errors and recognition outcomes in these two tasks across both groups.