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Developmental plateau in visual object processing from adolescence to adulthood in autism

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ABSTRACT

A lack of typical age-related improvement from adolescence to adulthood contributes to face recognition deficits in adults with autism on the Cambridge Face Memory Test (CFMT). The current studies examine if this atypical developmental trajectory generalizes to other tasks and objects, including parts of the face. The CFMT tests recognition of whole faces, often with a substantial delay. The current studies used the immediate memory (IM) task and the parts-whole face task from the Let's Face It! battery, which examines whole faces, face parts, and cars, *without* a delay between memorization and test trials. In the IM task, participants memorize a face or car. Immediately after the target disappears, participants identify the target from two similar distractors. In the part-whole task, participants memorize a whole face. Immediately after the face disappears, participants identify the target from a distractor with different eyes or mouth, either as a face part or a whole face.

Results indicate that recognition deficits in autism become more robust by adulthood, consistent with previous work, and also become more general, including cars. In the IM task, deficits in autism were specific to faces in childhood, but included cars by adulthood. In the part-whole task, deficits in autism became more robust by adulthood, including both eyes and mouths as parts and in whole faces. Across tasks, the deficit in autism increased between adolescence and adulthood, reflecting a lack of typical improvement, leading to deficits with non-face stimuli and on a task without a memory delay. These results suggest that brain maturation continues to be affected into adulthood in autism, and that the transition from adolescence to adulthood is a vulnerable stage for those with autism.

1. Introduction

Individuals with autism exhibit impaired face recognition but the reasons for this deficit are unknown (Sasson, 2006; Weigelt, Koldewyn, & Kanwisher, 2012). It is unclear if this deficit is associated with the social impairment that is diagnostic of autism (e.g., a lack of social motivation leads to less expertise with faces; Dawson, Webb, & McPartland, 2005; Schultz, 2005), with general differences in visual processing (e.g., a 'local bias' undermines holistic processing important for face recognition; Behrmann, Thomas, & Humphreys, 2006b; Happe, 1999; Mottron, Dawson, Soulières, Hubert, & Burack, 2006), or with both. The lack of clarity on this issue reflects the evidence; deficits in recognition in autism are sometimes specific to faces (Bradshaw, Shic, & Chawarska, 2011; Wolf et al., 2008) and sometimes apply to a range of objects (e.g., motorcycles; Blair, Frith, Smith, Abell, & Cipolotti, 2002). In this paper, we examine how the deficit changes with age, with the hope that the progression of the visual differences in autism will clarify the etiology of the deficit and its impact on visual function.

Adolescent development has proven important for understanding visual differences in adults with autism (Kuschner, Bodner, & Minshew, 2009; O'Hearn, Lakusta, Schroer, Minshew, & Luna, 2011; O'Hearn, Schroer, Minshew, & Luna, 2010; Rump, Giovannelli, Minshew, & Strauss, 2009; Scherf, Luna, Kimchi, Minshew, & Behrmann, 2008), although most of the studies on age-related changes in autism focus on the initial development of this early-emerging disorder (e.g., Chawarska & Shic, 2009). We previously examined changes during adolescence in face recognition using a well-established face memory task (the Cambridge Face

Abbreviations: TD, typically developing; IM, immediate memory; LFI, Let's Face It; CFMT, Cambridge Face Memory Test.

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Memory Test, CFMT, described below). Performance on the CFMT improved from adolescence to adulthood typically, but did not improve during this transition in individuals with autism (O'Hearn et al., 2010). These results were surprising for two reasons. One, typical development of face recognition continued into adulthood, a finding later replicated in a larger sample of typically developing (TD) individuals (Germine, Duchaine, & Nakayama, 2011; while face recognition has long been considered late developing for vision, "late" was considered around age 12, Carey & Diamond, 1977; Mondloch, Geldart, Maurer, & Le, 2003). Two, face recognition deficits in autism became more robust in adulthood, despite the early emergence of autism and the potential for individuals with autism to learn compensatory strategies by adulthood. The lack of typical adolescent development in autism has far-reaching implications, because evidence suggests that it is quite general; some studies show a lack of development on visual tasks without face stimuli or a memory component (rapid enumeration of a few elements, O'Hearn, Franconeri, Wright, Minshew, & Luna, 2013; global shape recognition, Scherf et al., 2008), and in analyses that controlled for memory deficits (i.e., change detection with and without people, controlling for memory span; O'Hearn, Lakusta, et al., 2011). These differences in the face recognition deficits between the adolescents and the adults with autism may reflect cohort effects, an important possibility to examine with longitudinal data. However, one indication that cohort effects are not the entire explanation is that the increasing deficits in autism, at least on the CFMT, are driven by improvements in typical developing controls. Therefore, the increasing deficits with age probably do not reflect the substantial changes in treatment, education, etc. for individuals with autism in the last few years. Longitudinal data will also be crucial for understanding the increased variability in those with autism, and whether some individuals with autism do undergo improvement during this developmental transition. Pragmatically, this lack of development suggests that those with autism may be falling further behind during the crucial transition to adulthood (Taylor & Seltzer, 2010).

One goal of the current study was to examine whether the deficit in autism is specific to whole faces, which are a unique set of stimuli in many ways, in order to provide insight into what is 'not developing' in autism. Faces are the stimuli most likely to be rapidly and universally processed at an individual level. Increasing expertise for faces over age may be driven by the unique amount and the quality of experience with faces, embedded in learning mechanisms specific to the developmental stage. These experiences may be disrupted in autism (de Haan, Humphreys, & Johnson, 2002; Schultz, 2005). Though contentious, the "specialness" of face processing is apparent in evidence of an innate bias (Morton & Johnson, 1991; Pascalis & de Schonen, 1994), dedicated neural tissue (Kanwisher, McDermott, & Chun, 1997)/circuitry (Haxby, Hoffman, & Gobbini, 2002), and the importance of holistic visual processing (Tanaka & Farah, 1993). Holistic processing is operationalized as a decline in performance when the upright face (or other stimuli) is distorted, most commonly by rotation (inversion tasks), combining faces (composite faces), or showing only a face part (part-whole task). While these disruptions may impair performance with other stimuli, the impact is greater with faces, indicating that holistic processing is particularly important for face recognition in TD adults (Yin, 1969). In addition, face recognition has been proposed to rely on specific types of configural information (e.g., 2nd order configural information, which is spacing between features; Behrmann et al., 2006a) that may be particularly important for identifying individual faces.

Research in autism has long tried to pinpoint if the recognition deficit in autism is specific to faces, or perhaps one of the unique characteristics of faces. For instance, several studies have suggested that individuals with autism rely less on configural information, which may be uniquely important for face recognition, than do TD adults (Behrmann et al., 2006b; Dawson et al., 2005). This could potentially result from the general 'local bias' in visual processing or a lack of experience with faces that disrupts the maturation of configural processing (Webb et al., 2011). However, a recent review by Weigelt et al., 2012 concluded that individuals with autism use holistic and/or configural processes that are qualitatively similar to TD individuals when recognizing faces, a conclusion that parallels recent work on normative development (McKone et al., 2012). The review stresses that, instead of configural processes, memory demands are an important factor that contributes substantially to the face recognition deficits in autism. Weigelt and colleagues also suggest that the deficits may be specific to faces, and even more specifically, to recognition of the eyes, although they acknowledge that the evidence for this conclusion is more ambiguous than their conclusion of the importance of memory demands. The possibility of eye-specific deficits are supported by the limited evidence of decreased fixations to the eyes in autism, or increased fixations on the mouth (less reliably), compared to TD groups. These differences in fixations are important for performance. They are correlated with face recognition performance (Kirchner, Hatri, Heekeren, & Dziobek, 2011; Weigelt et al., 2012), as well as activation in the fusiform gyri both typically (Morris, Pelphrey, & McCarthy, 2007) and in autism (Dalton et al., 2005; Perlman, Hudac, Pegors, Minshew, & Pelphrey, 2011).

Our initial work showing a lack of development in autism from adolescence to adulthood used the Cambridge Face Memory Test (CFMT; O'Hearn et al., 2010), developed to identify adults with prosopagnosia (Duchaine & Nakayama, 2006). This task has three conditions, with each condition increasing in difficulty. In the first condition, participants are told to memorize six target faces. Each face is memorized consecutively, across three memorization trials and three test trials. During the memorization trials, participants see the target face from three angles (3 s each). After the memorization trials, there are three test trials where participants identify the same images of the target face from two distractors. The second and third conditions are similar except that: (1) there is only one memorization trial, albeit longer (20 s), with the 6 target faces presented simultaneously. This means that the memory delay is increased when recognizing faces, especially for later test trials, and (2) the test stimuli images are not the same as the memorization images, but instead are displayed with novel angles/lighting and, in the third condition, blur. Performance in all three conditions displayed the same pattern of age-related improvement during adolescence typically but not in autism, despite the differences across conditions in the length of the delay and, in condition 3, the blurred images (thought to require more configural processing). Further work has replicated our findings of deficits on the CFMT in adults with autism (Kirchner et al., 2011), including individuals who do not display early communication deficits (Aspergers; Hedley, Brewer, & Young, 2011) and unaffected relatives of individuals with autism (Wilson, Freeman, Brock, Burton, & Palermo, 2010).

The current studies further characterize these age-related changes in recognition, including the typical improvements during adolescence, and how it differs in autism. We examine whether the deficit in autism is specific to face stimuli (by comparing faces vs. cars) or to holistic processing (by comparing whole vs. part faces). We also examined whether these distinct trajectories, typically and in autism, were evident on a task with no delay between memorization and test.[1] To address these questions, we chose two tasks from the *Let's Face It!* (LFI) battery, one that tested immediate memory (IM task) for faces and cars, and one that tested holistic processing of faces (part-whole task). The LFI battery was developed for

[1] We did not use a task with simultaneous presentation, because these tasks differ from typical face recognition and the stimuli have to be challenging in some way.