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Ensemble perception of emotions in autistic and typical children and adolescents

Themelis Karaminis[a,b,*], Louise Neil[a], Catherine Manning[a,c], Marco Turi[d,e], Chiara Fiorentini[f], David Burr[d,g], Elizabeth Pellicano[a,g]

[a] Centre for Research in Autism and Education (CRAE), UCL Institute of Education, University College London, UK
[b] Department of Psychology, Plymouth University, Plymouth, UK
[c] Department of Experimental Psychology, University of Oxford, Oxford, UK
[d] Department of Psychology, University of Florence, Florence, Italy
[e] Fondazione Stella Maris Mediterraneo, Chiaromonte, Potenza, Italy
[f] School of Psychology, University of Geneva, Switzerland
[g] School of Psychology, University of Western Australia, Perth, Australia

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ABSTRACT

Ensemble perception, the ability to assess automatically the summary of large amounts of information presented in visual scenes, is available early in typical development. This ability might be compromised in autistic children, who are thought to present limitations in maintaining summary statistics representations for the recent history of sensory input. Here we examined ensemble perception of facial emotional expressions in 35 autistic children, 30 age- and ability-matched typical children and 25 typical adults. Participants received three tasks: a) an 'ensemble' emotion discrimination task; b) a baseline (single-face) emotion discrimination task; and c) a facial expression identification task. Children performed worse than adults on all three tasks. Unexpectedly, autistic and typical children were, on average, indistinguishable in their precision and accuracy on all three tasks. Computational modelling suggested that, on average, autistic and typical children used ensemble-encoding strategies to a similar extent; but ensemble perception was related to non-verbal reasoning abilities in autistic but not in typical children. Eye-movement data also showed no group differences in the way children attended to the stimuli. Our combined findings suggest that the abilities of autistic and typical children for ensemble perception of emotions are comparable on average.

1. Introduction

Human perception will often seek the summary, the texture or the 'gist' of large amounts of information presented in visual scenes. Large amounts of similar objects, for example, some books on a shelf, or the buildings of a city may give rise to group precepts – the percept of a book collection or a city view. Properties of group percepts – whether a book collection is tidied up or not, whether a view belongs to an old or a contemporary city – seem to be accessible rapidly and effortlessly, and with little awareness of details differentiating individual elements.

This ability to assess automatically the summary or 'gist' of large amounts of information presented in visual scenes, often referred to as ensemble perception or ensemble encoding, is crucial for navigating an inherently complex world (Chong and Treisman, 2003, 2005; Haberman and Whitney, 2009; Sweeny et al., 2013). Given the processing limitations of the brain, it is often efficient to sacrifice representations of individual elements in the interest of concise, summary representations, which become available as the brain rapidly encodes statistical regularities in notions of a 'mean' or a 'texture' (Haberman and Whitney, 2012; Whitney et al., 2013).

Ensemble perception has been demonstrated consistently for low-level visual attributes, including size, orientation, motion, speed, position and texture (Ariely, 2001; Chong and Treisman, 2003; Parkes et al., 2001). More recently, studies have also demonstrated ensemble perception in high-level vision. In Haberman and Whitney (2007)'s initial work on ensemble perception – and on which the current study was based, three adult observers

* Corresponding author at: Centre for Research in Autism and Education, UCL Institute of Education, University College London, 55–59 Gordon Square, London, WC1H 0NU, UK.
E-mail address: themkar@gmail.com (T. Karaminis).

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viewed sets of morphs (computer-generated continuous variations of expressions of the same face) ranging from sad to happy. Observers were then asked to indicate whether a subsequent test face was happier or sadder than the average expression of the set, a task that required creating an internal representation of an *average* of facial expressions in the first set. The precision with which the three observers completed this task was remarkably good. In fact, two of the three observers were as precise in discriminating ensemble emotions as they were in identifying the emotions of single faces (in a control task). In another task, the same observers viewed sets of emotional morphs and were subsequently asked to indicate which of two new morphs was a member of the preceding set. All three observers were unable to perform above chance in this condition, suggesting that observers were unable to encode information about individual face emotions, despite being able to encode seemingly effortlessly information about average emotions. Subsequent work has shown these effects for a range of facial attributes (gender, ethnicity, identity, emotion, attractiveness; Haberman et al., 2009; Haberman and Whitney, 2007, 2009, 2010, 2011; Neumann et al., 2013).

Sweeny et al. (2014) have also shown that ensemble perception of size is also present, though not yet fully developed early in development, in 4–6 year-old children. In the primary condition of their child-friendly task, participants saw two trees, each containing eight differently sized oranges, and were asked to determine which tree had the largest oranges overall. A secondary condition (see Sweeny et al., 2014) included experimental manipulations that allowed for the empirical simulation of performance in the primary condition with no ensemble coding strategies available—that is, as if participants gave their response after comparing the sizes of a single, randomly-chosen orange from each tree. The difference in accuracy between the primary and secondary conditions provided an estimate of the extent to which participants benefited from the use of ensemble perception strategies, the 'ensemble coding advantage' (Sweeny et al., 2014). They found significant ensemble coding advantages in both young children and adults, although children presented smaller such advantages than adults. An ideal observer model, which was also used to predict the minimum number of items integrated in the primary condition, suggested that both children and adults did not necessarily derive ensemble codes from the entire set of items ($N = 16$), while children integrated fewer items than adults (4.24 vs. 7.18 items, correspondingly, across both trees), consistent with the smaller ensemble coding advantage they exhibited.

In the current study, we examined ensemble perception of emotions in autistic children and adolescents, and contrasted these with typical children, adolescents and adults. Autism is a highly heterogeneous neurodevelopmental condition known for difficulties in social interaction and communication. However, autism is also characterised by atypicalities in sensation and perception (DSM-5; American Psychiatric Association, 2013; see Simmons et al., 2009; for review). Many studies have focused on the processing of social stimuli and of faces in particular. This literature presents a confusing picture. While many studies have reported that autistic children present pervasive difficulties in emotion discrimination (see Uljarevic and Hamilton, 2012; for review), other studies have found such difficulties specifically for negative or more complex emotions (Jones et al., 2011) or no difficulties at all (Ozonoff et al., 1990; Tracy et al., 2011).

Prominent theories have suggested difficulties in social perception might be driven by fundamental problems in global processing (weak central coherence; Happé and Frith, 2006) or a local-processing bias that leads to strengths in the processing of simple stimuli and to weaknesses in the processing of more complex stimuli (Mottron et al., 2006). We have suggested that the unique perceptual experiences of individuals with autism might be accounted for by attenuated prior knowledge within a Bayesian computational model of perceptual inference (Pellicano and Burr, 2012). This hypothesis posits limitations in the abilities of individuals with autism to derive, maintain and/or use efficiently summary statistics representations for the recent history of sensory input. Such limitations lead to a processing style where sensory input is modulated to a lesser extent by norms derived from prior sensory experience.

Karaminis et al. (2016) have recently demonstrated this account formally, in the context of temporal reproduction, using a Bayesian computational model for central tendency (Cicchini et al., 2012), which suggested that the phenomenon reflects the integration of noisy temporal estimates with prior knowledge representations of a mean temporal stimulus. Karaminis et al. (2016) contrasted the predictions of this ideal-observer model with data from autistic and typical children completing a time interval reproduction task (measuring central tendency) and a temporal discrimination task (evaluating temporal resolution). The simulations suggested that central tendency in autistic children was much less than predicted by computational modelling, given their poor temporal resolution.

Pellicano and Burr's (2012) hypothesis has also received empirical support from studies showing diminished adaptation in the processing of face (e.g., Pellicano et al., 2007; Pellicano et al., 2013) and non-face stimuli (e.g., Turi et al., 2015; van Boxtel et al., 2016). Such findings appear to generalise to ensemble perception, i.e., summary statistics representations derived on a trial-by-trial basis from stimuli presented *simultaneously* and for brief time intervals. Rhodes et al. (2015) have developed a child-appropriate version of a paradigm for ensemble perception of face-identity (Neumann et al., 2013), which they administered to 9 autistic children and adolescents and 17 age- and ability-matched typical children. These authors found reduced recognition of averaged identity in autistic participants.

In the current study, we evaluated two predictions, based on Pellicano and Burr (2012), for the patterns of performance of autistic and typical children and adolescents (aged between 6 and 18 years; hereafter 'children') by developing a developmentally-appropriate version of Haberman and Whitney (2007)'s paradigm for ensemble perception of emotions.

First, we predicted that autistic children should present difficulties in Task 1 assessing average emotion discrimination (see Fig. 1), evidenced by lower precision than typical children in the average relative to the baseline emotion discrimination task (as autistic children/adolescents might present general difficulties in emotion discrimination; Uljarevic and Hamilton, 2012). We further tested this prediction using computational modelling and eye-tracking methodologies. Computational simulations (akin to Sweeny et al., 2014) should suggest a weaker ensemble coding advantage and fewer items sampled in autistic children compared to typical children. Eye-tracking data could also reveal atypicalities in the ways autistic children attended to the stimuli (e.g., in the number of faces sampled).

Second, we predicted that autistic children should perform *better* than typical children in Task 3, identifying emotional morphs that had been previously presented to them. This advantage could be due to a greater reliance upon detailed representations of individual items, which are more important in this particular task, rather than on summary statistics (cf. Happé and Frith, 2006; Pellicano and Burr, 2012).

Finally, we also included a group of typical adults to examine developmental differences between children and adults in ensemble perception of emotions. We hypothesised that children were likely to show reduced abilities for ensemble perception compared to adults, similar to Sweeny et al.'s (2014) findings for the development of ensemble perception of size.