Experiment Proposal:

Effects of Face Recognition Training on 5-6 Year-Olds

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Human face perception has long been a topic of extensive psychological inquiry. The tremendous capacity for humans to differentiate and recognize the varied and numerous faces encountered daily is impressive to say the least. Several questions regarding face perception have arisen in the past 20 years, such as how we code faces into memory, whether our face recognition abilities are inborn or learned, or whether there are specific brain modules devoted to face perception and processing. The present study addresses in part those two latter questions.

Morton and Johnson (1991) were early researchers into infant face perception. Their study aimed to investigate whether newborn infants possess some information regarding the structure of faces. Previous studies (see Haaf, 1974; Haaf, Smith, & Smitty, 1983) had shown infants show no preference for faces until 4 months. Using a new technique (measuring the mean degree of rotation of the infants' eyes and heads), however, Morton and Johnson found significant results indicating a preference for face-like patterns in infants. To explain these findings they suggested a two-process theory for the development of face recognition in humans (namely CONSPEC – guiding preference for face-like patterns in newborns, and CONLERN – guiding learning about the visual characteristics of 'conspecifics'). In essence, their study provided early evidence for an inborn human ability to recognize faces.

In the same vein as the work of Morton and Johnson (1991), Kanwisher, McDermott, and Chun (1997) found an area in the fusiform gyrus that was significantly more active when subjects viewed faces as opposed to other common objects. Using functional magnetic resonance imagining (fMRI), they found that this area (referred to as the fusiform face area or FFA) responded significantly more strongly to images of intact (rather than scrambled) faces, images of front-view faces (rather than houses), and images of partially concealed faces (rather than human hands). Based on these data, the researchers concluded that the FFA is selectively involved in the perception of faces (rejecting alternative accounts that it is related to visual attention, subordinate-level classification, or general processing of any animate forms).

In contrast to data suggesting that the FFA responds selectively to faces, Gauthier, Tarr, Anderson, Skudlarski, and Gore (1999) argued that the FFA is not dedicated specifically to face perception, but to the perception of members of an expertise category (e.g. the category of birds for an ornithologist). They argued this point based on fMRI data showing that by training participants to better identify novel objects (greebles), participants showed greater activation in right hemisphere face areas when matching upright (compared to inverted) greebles and when passively viewing greebles compared to novices. Based on this shared activation of right hemisphere face areas, Gauthier et al. argued that expertise is the relevant factor leading to the specialized use of the face area.

Rhodes, Byatt, Michie, and Puce (2004) also attempted to determine the functional role of the FFA. They sought to choose between three competing hypotheses: face specificity (also known as domain-specificity), individuation, and expert individuation. They defined face specificity as the hypothesis that the FFA is specialized for face processing (see Kanwisher et al., 1997). They defined individuation as the hypothesis that the FFA is for individuating visually similar members of a category. They defined expert individuation as the hypothesis that the FFA is for individuating within categories with which one has expertise. In two fMRI experiments, Rhodes et al. found that FFA activation was greater for faces than either objects or members of an expertise category. Furthermore, they found that there was little overlap in areas of the fusiform gyrus activated by faces and expertise category members. These results indicate, in opposition to the work of Gauthier et al. (1999), support for the domain-specificity hypothesis.

Responding to the debate between the domain specificity hypothesis (see Rhodes et al., 2004) and the expertise hypothesis (see Gauthier et al., 1999), McKone, Kanwisher, and Duchaine (2007) reviewed data testing these two hypotheses. After summarizing data testing whether face-selective effects (i.e. holistic processing, recognition impairments in prosopagnosia, and FFA activation) remain selective compared to objects of expertise (e.g. the birds for an ornithologist), McKone et al. concluded that the evidence more strongly supported the domain specificity hypothesis than the expertise hypothesis. Based on their review, the researchers finally concluded that face recognition does not simply reflect a practice effect and that it might be supported by evolved biological mechanisms.

As demonstrated, there is a substantial body of evidence in support of FFA specialization for face recognition. The specific mechanism of this specialization was a matter of debate for some time, however, in opposition to the expertise hypothesis (e.g., Gauthier et al., 1999; Gauthier, Curran, Curby, & Collins, 2003) the current opinion on the matter tends toward the domain specificity account (e.g., Kanwisher et al., 1997; McKone et al., 2007; Rhodes et al., 2004). There is still some debate, however, as to how the FFA and other face areas become specialized for face processing. A leading account of this process is the theory of interactive specialization. It states that facial recognition expertise and FFA dedication occur over development and as children gain experience receiving different visual stimuli (de Hann, Humphreys, & Johnson, 2002).

Working within the assumptions of the domain specificity account, one of the first studies to explore face area specialization over development was that of Passarotti et al. (2003). By concurrently comparing the patterns of fMRI activation in children ages 10-12 to those of adults the researchers found a developmental shift from a distributed pattern of activation in children to a more focused pattern in adults. This shift was observed in both the medio-lateral fusiform region (i.e. the FFA) and the middle temporal gyrus for a face recognition task. These results indicate that there is a change in the pattern of functional activation over development from distributed (children) to focused (adult).

A similar patter of results to those of Passarotti et al. (2003) was found by Scherf, Behrmann, Humphreys, and Luna (2007). The investigated the differences in developmental trajectories for face, object, and place selective neuronal activation. They found that children demonstrated adult-like activation in place and object related cortices, they did not show consistent face selective activation in classic face regions. Their findings indicate that specialized processing of face stimuli is delayed developmentally relative to specialization for object and place perception.

Although the interactive specialization theory states that the FFA becomes a dedicated module over development, and past research seems to indicate that this specialization is correlated with a change from distributed activation for visual stimuli in children to a more focused pattern in adults, the question remains open as to what mechanism of action causes this developmental change. Two possible explanations seem plausible: experience processing faces creates a practice-induced functional specialization (*experience specialization*), or the time-dependent biological developmental trajectory of children determines this specialization (*biological specialization*). The present study aims to further explore the theory of interactive specialization by discerning the extent to which experience specialization and biological specialization affect its acquisition.

This discernment will be accomplished by extensively training a group of 5-6 year olds in facial recognition tasks and measuring changes in their functional activation during face perception tasks as well as changes in their performance on face processing expertise marker tasks (see methods) compared to controls and adults over a period 6 years.

Regardless of the mechanism of action responsible for interactive specialization, all training conditions should display adult-type activation during face perception tasks and during their performance on face processing expertise marker tasks after 6 years (when they are 11-12 years old) (see Passarotti et al, 2003; Scherf et al, 2007). If experience specialization is the mechanism responsible for interactive specialization, the trained children should progressively approach adult-type activation and performance relative to controls and adults after one and two years of face recognition training. If biological specialization is the mechanism responsible, trained and control children should show no significant difference in their functional activation or performance and their approach of adult-type activation and performance should equivalent – that is, solely dependent on time.

Hypothesis

Based on the development of expertise in working with novel objects demonstrated by Gauthier et al. (1999) it is hypothesized that experience specialization is the mechanism of action responsible for interactive specialization. It is also hypothesized that regardless of their training condition, by 11-12 years the participants will have the same (adult-like) functional activation during face perception tasks as well similar performance on face processing expertise marker tasks (see Scherf et al., 2007).

Design of Experiment

Child participants (ages 5-6) will be trained in one of three conditions (between-subjects). These conditions will consists of a face recognition training condition, a Lepidoptera (moths and butterflies) recognition training condition, and a control mathematics training condition (see methods). Children will be tested four times – once before training, once after one year of training, again after two years of training, and finally after six years from the baseline assessment (resulting in twelve sets of testing data). A group of adults will be tested once during the time of baseline assessment to provide a template for adult (expert) face perception task performance. Testing will consist of two neuroimaging tasks, one of which will test neuronal activation during passive face viewing and one which will test activation during a face matching task (see methods). Two additional measures (which act as face recognition expertise marker tasks) will also be administered at each testing occasion for all participants.

To test the first hypothesis, that experience specialization is the mechanism of action responsible for interactive specialization, baseline neuroimaging and marker task data from children in all three conditions will be compared to the data for adults to ensure that they demonstrate a child (novice) level of face perception expertise and activation distribution. Any children who do not demonstrate significantly different activation from adults on both neuroimaging tasks will be replaced by new participant recruits. After one year and two years of training, the mean for children in the face recognition training condition will be compared to the baseline adult mean on the basis of the distribution their of neuronal activation during neuroimaging tasks one and two. The children in the face recognition training condition will also be compared to those in the Lepidoptera training condition and the control mathematics training condition after one and two years to ensure that any difference in neuronal activation (between children in the face recognition training condition and adult baselines) shown in neuroimaging tasks one and two are due to the effects of their training condition alone.

Finally, after six years, the children in all three training conditions will again be compared to the adult baselines on the basis of their neuronal activation during neuroimaging tasks one and two for the purpose of testing the second hypothesis and testing that the present studies' methods faithfully replicate those used by Scherf et al. (2007) (with the exception that the present study will ultimately use a within-subjects design to compare patterns of activation between 5-6 year olds and 11-12 year olds).

The face recognition expertise marker tasks will serve to verify that the training of children in face recognition and Lepidoptera recognition are valid – i.e. that training face recognition or Lepidoptera recognition improves face and Lepidoptera recognition ability respectively, and the is no 'general expertise' in recognizing complicated stimuli garnered as a result participants' training in general.

Method

Participants

The participants in this study will be male volunteers recruited from London (Ontario) elementary schools with parental consent. 60 children ages 5-6 and 20 adults will be recruited. The child participants recruited for the study will be a convenience sample, and will receive $10 per day for their participation in training after school each day and $25 for each test day. The adults recruited will be drawn from the University of Western Ontario fMRI study pool, and will receive $25 for their one test day. Participants will be right-handed, native English speakers, and will have normal or corrected vision.

Specific Procedures

Participants were administered four different test measures. The proposed procedure of each measure is outlined below. Additionally, the procedures for the administration of the three training conditions are outlined.

Face Recognition Expertise Marker Task 1

This task is based on that used by Tanaka (2001, p. 535) to test whether adults can identify faces at the subordinate level (e.g., Stephen Hawking) as frequently as at the ordinate level (i.e., human). Participants will be seated directly across from the experimenter. They will be presented pictures approximately every 2s by the experimenter. The order of presentation will be randomized (with the exception that on no two trials will participants be presented with a ‘famous face’). The experimenter will score the category level (subordinate or ordinate) of each response. Responses will be scored as described by Tanaka (p. 535), including the omission from analysis of any pictures which participants could not name at a more subordinate level.

Tanaka (2001) found that face expertise, like object expertise, caused a downward shift in recognition to more subordinate levels. Given these results, by providing children and adults with similar stimuli while using the same procedure, it is expected that adults will use a more subordinate level of abstraction than children – and as such participants’ performance on this task will be indicative of their face processing expertise.

Face Recognition Expertise Marker Task 2

This task is based on the Multidimensional Scaling Analysis (MDS) used by Nishimura, Maurer, and Gao (2009). Using the same procedure as Nishimura et al. (p. 363), each participant will be tested individually in a dimly lit room 100cm from the stimulus (presented on a colour computer monitor), and will begin by being explained the task, followed by a demonstration trial. Participants will then perform six validity trials with transportation vehicles to verify that they have understood the odd-man-out paradigm to be used. If they complete all six validity trials correctly, they will move on to six practice trials with faces. Participants will then complete 200 test trials by either verbal or mouse click response, with 3 faces presented in the same layout as the practice trials. Triad formation will be randomized across participants as described by

Nishimura et al. (p. 363). After every 15 to 30 trials, there will be an extra trial in which participants will be free to take a break if needed.

Nishimura et al. (2009) found that “children relied heavily on a single dimension, likely eye color, when making similarity judgments, whereas adults used all five dimensions more equally” (p. 372). By requiring participants to make facial similarity judgments in an ‘odd-man-out’ paradigm as explicated above, this task will use the resultant MDS averages to indicate what dimensions each participant is using to make similarity judgments, and thereby extrapolate whether the participant is displaying expert (adult-type) or novice (child-type) facial perception abilities.

Neuroimaging Task 1

This task is taken from the study by Scherf et al. (2007, p. 17) to test MRI activation across development in response to faces, places, and objects. Before the scanning session, all participants will be trained for 20 minutes in a mock scanner that will simulate the environment of an actual MRI scanner. Participants will then view a silent, continuous set of short movie vignettes, containing scenes of faces, buildings, navigation through open fields, or miscellaneous common objects (see Hasson, Nir, Levy, Fuhrmann, & Malach, 2004). Following Scherf et al., the vignettes will be organized into 32 randomized 15-second blocks, containing stimuli from a single category. The task will begin with a 29-second blank screen followed by a 9-second block of abstract pattern stimuli and will end with a 21-second blank screen.

Participants’ resultant pattern of activation in four traditional face areas, namely the FFA, the parahippocampal place area (PPM), the occipital face area (OFA), and the superior temporal sulcus (STS) should prove indicative of whether they display evidence of specialized areas for face processing.

Neuroimaging Task 2

To further assess the level of distribution of neuronal activation, participants will be given a face matching task as described in Passarotti et al. (2003, p. 104-105). All participants will undergo a short behavioral practice session before the brain imaging session. The imaging session should last approximately 30 minutes. Each trial will begin with a 500ms fixation cross, followed by a 1000ms ISI. The first reference face will then appear at the fixation cross for 500ms, and after 250ms ISI, a second reference face will appear for 500ms. A third ISI of 1750ms will then appear, followed by the target face for 2000ms. There will be an intertrial interval of 500ms. Within each block of trials there will be an equal number of matched and mismatched response trials. Participants will decide whether the target face matched either of the two previous probe faces, responding with a binary 'yes' or 'no.' The location-matching task and concurrent reaction time measures described by Passarotti et al. will be excluded from the present study.

Passarotti et al. (2003) found that even though children and adults did not differ on the overall amount of activation in either the medio-lateral fusiform region or the middle temporal region (the experimenters' regions of interest) they did differ significantly in the distribution of this activation (i.e. children showed a more distributed pattern of activation than adults). As such, participants' pattern of activation in this task should again prove indicative of whether they display evidence of specialized areas for face processing.

Face Recognition Training

Participants in the face recognition training condition will be trained at a computer monitor, and their daily training will take 1 hour. Participants will be presented randomized blocks of three training exercises, namely scrambled image recognition, upside down image recognition, and an odd-man-out recall exercises.

In the scrambled image exercise, participants will be presented a fixation cross for 1s, a scrambled image of a face for 1s, then will be presented 3 options and will be asked to respond via mouse click as to which image matches the scrambled one presented previously.

In the upside down image recognition task, participants will be presented a fixation cross for 1s, an upside down image of a face for 1s, and then will be presented 3 options and will be asked to respond via mouse click as to which image matches the upside down one presented previously.

In the odd-man-out exercise participants will be presented a fixation cross for 1s, a set of 6 faces (arranged 2x3 horizontally) for 3s, and then will be presented the same set of 6 faces except with one face replaced with a different face. Participants will then be asked to respond via mouse click as to which image was not present previously.

Lepidoptera Recognition Training

Participants in the Lepidoptera (butterflies and moths) recognition training condition will also be trained at a computer monitor, and their daily training will take 1 hour. Participants will be presented randomized blocks of three training exercises, namely scrambled image recognition, upside down image recognition, and an odd-man-out recall exercises.

In the scrambled image exercise, participants will be presented a fixation cross for 1s, a scrambled image of a Lepidopteran for 1s, then will be presented 3 options and will be asked to respond via mouse click as to which image matches the scrambled one presented previously.

In the upside down image recognition task, participants will be presented a fixation cross for 1s, an upside down image of a Lepidopteran for 1s, and then will be presented 3 options and will be asked to respond via mouse click as to which image matches the upside down image presented previously.

In the odd-man-out exercise participants will be presented a fixation cross for 1s, a set of 6 images of Lepidoptera (arranged 2x3 horizontally) for 3s, and then will be presented the same set of 6 images except with one Lepidopteran replaced with a different Lepidopteran. Participants will be asked to respond via mouse click as to which image was not present previously.

Control Condition

In the control condition, participants will practice addition or subtraction at a computer monitor, and the daily training will take 1 hour. Math exercises will again come in blocks of 3.

Materials

Participants were administered four different measures. Each measure administered is outlined below. Additionally, the materials for each of the three training conditions are outlined.

Face Recognition Expertise Marker Task 1

Stimuli for this task will follow those used by Tanaka (2001, p. 535) and will consist of pictures of objects and famous faces. Object pictures will be drawn directly from his study (46 black-and-white drawings and photographs taken from 11 artefact categories and 9 natural categories. Object stimuli will contain sufficient detail to be identified at the subordinate level. The four face stimuli will be selected based on the results of a pilot study such that they are correctly named by at least 75% of adults and children ages 5-6.

Face Recognition Expertise Marker Task 2

Stimuli for this task will follow those used by Nishimura et al. (2009, p. 362). 13 distinctive and 12 typical faces will be used to form a balanced incomplete block design.

Neuroimaging Task 1

Stimuli for this task will follow those used by Scherf et al. (2007). They will consist of movie vignettes corresponding to each category used in the original study – "[t]he movie categories included close-up shots of novel faces in natural situations (e.g. looking at the camera while walking through a crowd), the camera panning through a building area, the camera panning through open fields, and objects being manipulated by hands (e.g. rolling dough with a rolling pin, whisking flour in a pot, picking up objects from a desk)" (Scherf et al., p. 16).

Neuroimaging Task 2

Stimuli for this task will follow those used by Passarotti et al. (2003, p. 104). 30 black-and-white photos of Caucasian male faces with neutral facial expressions will be obtained from the database of the University of Essex (UK), and edited in Adobe Photoshop to fit the specifications listed by Passarotti et al.

Face Recognition Training

Faces presented will be color photographs of faces drawn from the internet (matched in frequency on dimensions of race, sex and distinctiveness, with distinctive hair cues removed). Scrambled faces will be divided into a 2x2 matrix, and the quadrants will be randomly rearranged. A database of several hundred photos will be compiled for the training exercises.

Lepidoptera Recognition Training

Lepidoptera presented will be color photographs drawn from the internet. Scrambled Lepidoptera will be divided into a 2x2 matrix, and the quadrants will be randomly rearranged. A database of several hundred photos will be compiled for the training exercises.

Control Training

Math exercises presented will be drawn from classroom exercise handbooks at the recommendation of participants' teachers.

General Procedure

All participants will receive a letter of information and verbal/written informed consent (informed verbal assent from children and informed written consent from their parents) will be acquired. All participants will then complete the four test measures (in the order presented above) to establish a baseline. Child participants will then be trained after every school day for 2 school years within their classrooms (with accommodation for random participant unavailability) for 1 hour according to their training condition. In all three training conditions, participants will be provided immediate feedback, and every 15 blocks participants will take a 2 minute break, with a 5 minute break every 15 minutes.

After both 1 year and 2 years of training child participants will again complete the four test measures as described above. 6 years after the initial baseline test measure assessment, when they are 11-12, child participants will complete their final round of the test measures. All participants will be compensated for their participation on a day-by-day basis.

Following standard magnetic resonance imaging procedures, with regard to neuroimaging tasks 1 and 2, earplugs will used to reduce scanner noise and foam pillows were positioned under the neck to help participants keep their head still. Thermoplastic masks made of polyform material will be used to stabilize participants' heads.

Data Analysis

Face Recognition Expertise Marker Task 1

Children in a given training condition will be compared with adults (or another training condition) on their mean percentage of subordinate stimulus attributions with a planned-comparison t-test (alpha .05). If several conditions are compared over time, the relevant split-plot Analysis of Variance (ANOVA) will be used to compare the average percentages for each condition.

Face Recognition Expertise Marker Task 2

The mean number of dimensions used to make similarity judgements (as given by an MDS analysis, see Nishimura et al., 2009) by participants in a given training condition will be compared with adults (or another training condition) on their mean number of dimensions used to make similarity judgements using a planned-comparison t-test (alpha .05). If several conditions are compared over time, the relevant split-plot ANOVA will be used to compare mean dimensions used for each condition.

Neuroimaging Task 1

Participants' patterns of activation in four traditional face areas, namely the FFA, the parahippocampal place area (PPM), the occipital face area (OFA), and the superior temporal sulcus (STS) will be compared on the basis of training condition. Face area activation comparisons will be done in accordance with the techniques used by Scherf et al. (2007) (i.e., F-tests with Tukey's HSD comparisons as required).

Neuroimaging Task 2

Participants' patterns of activation in the regions of interest (i.e. middle temporal region and medio-lateral fusiform regions) will be compared on the basis of training condition. Face area activation comparisons will be done in accordance with the statistical techniques used by Passarotti et al. (2003) (i.e., two-way ANOVAs).

Discussion

It is hypothesized that experience specialization is the mechanism of action responsible for interactive specialization. For this prediction to be confirmed by the results children in the face recognition training condition would have to display similar patterns of activation to adults in neuroimaging tasks one and two after one or two years of training, while the other training conditions did not show similar patterns to adults. This confirmation of the first hypothesis would provide a significant contribution to theory surrounding the acquisition of specialization in face processing, and could have implications generally regarding the acquisition of face processing expertise.

If the present study's first hypothesis is not confirmed, and children's patterns of neuronal activation do not change as a result of face recognition training, this result could have two different implications. If it is the case that training has no effect on children's performance in any task whatsoever and task performance in children is only found to be comparable to adults after six years, it would indicate that the biological specialization explanation is the mechanism of action for the formation of interactive specialization. If however, it is found that the performance of children on the marker tasks is similar to that of adults while their neuronal activation is not, it might indicate that instead of a concentration in neuronal activation over development, pattern coding in the firing of FFA (or other classical face processing regions) neurons is responsible for changes in face processing expertise.

It is also hypothesized that regardless of training, by 11-12 years the participants will have the same (adult-like) functional activation during face recognition tasks and passive face viewing as well as similar performance on face processing expertise marker tasks (as demonstrated by Scherf et al., 2007). If children do not have adult-like functional activation during neuroimaging tasks nor during expertise marker tasks, it would indicate a limitation on the effects found by Scherf et al., the investigation of which would be a direction for future research. Alternatively, it could mean that the present studies' methods did not faithfully replicate those used by Scherf et al. – in which case there might exist a theoretically important difference between their methods and the methods of the present study.

The findings of the present study could have several practical implications. Firstly, if it is found that face recognition training does significantly affect neuronal activation and marker task performance in children, it might indicate that other assumed biological developmental phenomena (e.g. spatial reasoning) could actually be ‘taught’ earlier than previously thought. Secondly, if it is found that training children to recognize Lepidoptera has the same effect as training them to recognize faces on their marker task performance and neuronal activation patterns, it could indicate the children possess common faculties for the recognition and manipulation of similar and intricate stimuli (and hence teaching school topics that require attention to various similar and intricate stimuli could be approached from ‘several angles’ by appealing to this shared faculty).

One direction for future research would be to explore the effects different types of training, with the aim determining whether the results of the present study are generalizable. Another research venture, if it is found that training does have a significant effect, would be to explore how early a child can receive face perception training and still benefit from it. Alternatively, if the findings of the present study indicate that facial recognition training is ineffective at shaping face perception expertise and neuronal activation patters, future research could explore whether a different type or timing of training could be effective.

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