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# Normal Greeble Learning in a Severe Case of Developmental Prosopagnosia

**Case Study**

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## Summary

**A central question in cognitive neuroscience is whether mechanisms exist that are specialized for particular domains. One of the most commonly cited examples of a domain-specific competence is the human ability to recognize upright faces. However, according to a widely discussed alternative hypothesis, face recognition is instead performed by mechanisms specialized for processing any object class for which an individual has expertise. Faces, according to this domain-general hypothesis, are just one example of an expert class. Nonface object expertise has been intensively investigated using a training procedure involving an artificial stimulus class known as greebles. A key prediction of this hypothesis is that individuals with face recognition impairments will also have impairments with other categories that control subjects have expertise with. Our results show that a man with severe prosopagnosia performed normally throughout the standard greeble training procedure. These findings indicate that face recognition and greeble recognition rely on separate mechanisms.**

## Introduction

Studies from neuropsychology (Farah, 1996; McNeil and Warrington, 1993; Moscovitch et al., 1997), neurophysiology (Gross et al., 1972; Kreiman et al., 2000), psychophysics (Young et al., 1987; Tanaka and Farah, 1993), and neuroimaging (Grill-Spector et al., 2004; Kanwisher et al., 1997; McCarthy et al., 1997) have provided evidence that upright face recognition is carried out by mechanisms that are dissociable from those used for object recognition. However, the domain of these dissociable mechanisms is unclear. They could be specialized for faces per se or specialized for a variety of expert object classes. There is no consensus in the literature regarding what constitutes expertise, and there are two competing conceptions of expertise. In what we'll call the "rapid" version (Gauthier and Tarr, 1997, 2002; Gauthier et al., 1998), expertise with a class can arise after less than 10 hr of training. In contrast, the "extended" version (Diamond and Carey, 1986; Carey, 1992) claims that expertise requires years to acquire.

To test the rapid view of expertise, we assessed whether a developmental prosopagnosic could perform normally in training with greebles. Greebles were designed to place similar demands on recognition systems as faces do. As can be seen in Figure 1, greebles have four features that are configured in a uniform manner so that subjects must rely on the shape of the features and/or the precise spatial relations of those features. The results of greeble training with normal subjects have been used to argue that training leads to effects that have been considered face specific but which could, in fact, be expertise specific. These include perceptual effects such as the composite effect (Gauthier et al., 1998; Gauthier and Tarr, 2002) and the old-new configuration effect (Gauthier and Tarr, 1997, 2002; Gauthier et al., 1998) as well as neural effects such as increased fusiform inversion effects in fMRI studies (Gauthier et al., 1999; Gauthier and Tarr, 2002) and increased N170s during ERP recordings (Rossion et al., 2002). Although many of these claims have been disputed (McKone and Kanwisher, 2004), greeble training is the standard method for the study of expertise. If face recognition is performed by mechanisms operating on items from "rapid" expert object categories, then individuals who are unable to acquire face expertise also should not be able to acquire expertise with other stimulus classes. However, if face expertise and other types of expertise depend on separate mechanisms, some individuals should show a dissociation between these two types of expertise.

## Results

### Case History

The prosopagnosic subject, Edward, reports lifelong difficulties with face recognition, and he has never suffered any serious head trauma. He recalls having difficulty recognizing even his father as a child, and his prosopagnosia has been a serious social handicap for him throughout his life. He is 53 years old, married, has PhDs in physics and theology, and works as a research physicist. Edward scored normally on all tests of low-level and mid-level vision. To properly test the rapid expertise hypothesis, it is important that prosopagnosics have normal object recognition, because prosopagnosics with object agnosia may perform poorly with the greebles due to object recognition difficulties. Edward reports no difficulties with object recognition, and our testing has not found any object impairments. He flawlessly named 100 line-drawn objects from the Snodgrass and Vanderwart (1980) set. On five tests of individual item object discrimination used in recent studies (Duchaine and Nakayama, 2004; Duchaine et al., 2003), Edward's accuracy and response times were in the normal range for cars, horses, tools, sunglasses, and guns, whereas he showed severely impaired performance in the same paradigm with faces.

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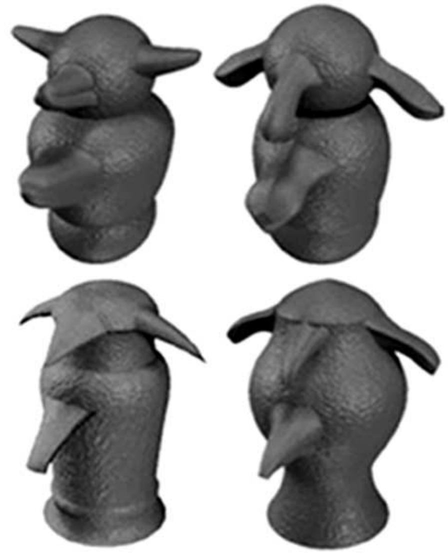

Figure 1. Examples of Greebles
The greebles in the top row are in the same family.

Our tests have shown that Edward is impaired with the discrimination of identity, emotion, and gender from the face. He was able to name only three famous faces out of 25 despite reporting substantial exposure to nearly all of the faces (see Figure 2A). A large sample of age-matched control subjects averaged 21.1 (SD = 3.6) on this test, so Edward's score places him more than six standard deviations below the mean. He has also performed poorly on tests of unfamiliar face memory. For example, the face one in ten test (Duchaine, 2000) requires subjects to discriminate between novel views of target and nontarget faces. Edward's d' score, an unbiased measure of discrimination, of 1.78 was almost four standard deviations below the control mean of 3.61 (SD = .49). In addition, his response times were more than ten standard deviations longer than the average control response times. On the Cambridge memory test for faces, subjects are introduced to six target faces and then are tested with forced choice items consisting of novel views of the target faces as well as two nontarget faces. In the introduction, subjects are tested on 18 items in which they know which target face will be presented. For the remaining 54 items, any of the six target faces can be presented. We compared Edward's performance to nine age-matched control subjects. On the items in the introduction, Edward responded correctly to 13 items, whereas all of the control subjects were perfect on all 18 items. In the final 54 items, Edward was correct on 26 items, whereas the controls averaged 43.8 (SD = 6.4) with scores ranging from 35 to 53. His total score was more than 3.5 standard deviations below the mean. In addition, recordings done with magnetoencephalography (MEG) found that Edward does not show the face-selective M170, which is found in normal subjects (Liu et al., 2000). Among the 35 developmental prosopagnosics that we have tested in our laboratory, Edward's impairment with faces is one of the most severe that we have seen.

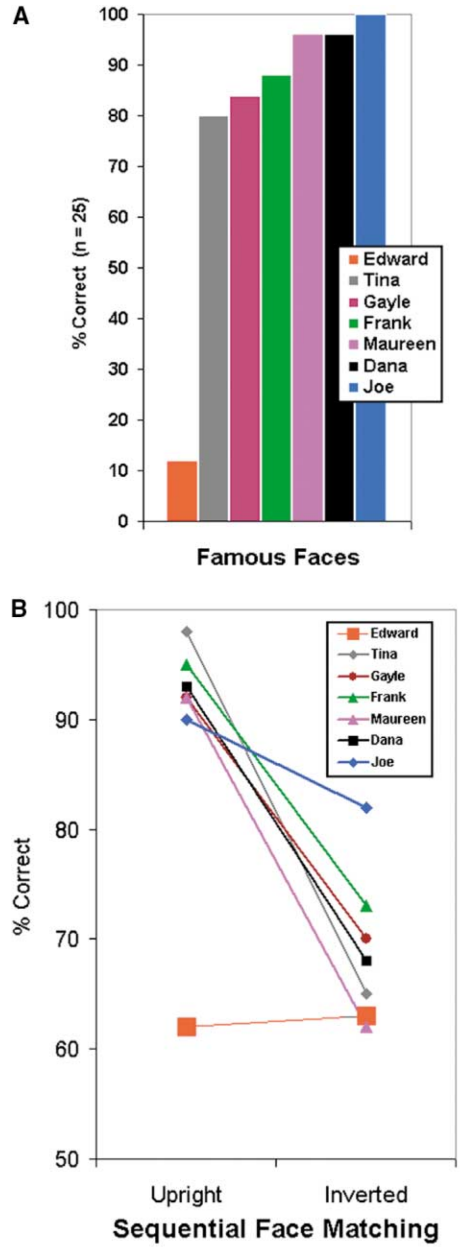


Figure 2. Face Recognition Results
(A) Percent correct for Edward and the control subjects on the famous faces test.
(B) Percent correct for the upright and inverted conditions in the sequential face matching test. There were two choices on each item, so chance is 50%.

For our purposes, it is essential to establish that he has little or no expertise with upright faces. To do this, we used a test of sequential face matching. A frontal shot of a face was presented for 400 ms and then two three-quarter profile shots were presented simultaneously for 1200 ms. Subjects were instructed to choose the three-quarter profile face that matched the frontal shot. Edward showed no advantage for upright matching compared to inverted matching (see Figure 2B), and his upright score was far out of the normal range while his inverted score was normal. A substantial advantage for upright over inverted face processing is the hallmark of face expertise (Yin, 1969; Diamond and Carey, 1986), so it appears that he has no expertise for upright faces despite 53 years of experience with them.

### Control Subjects

The six control subjects had either a Master's degree or a PhD (2 men, 4 women, mean age = 48, SD = 10.2). To confirm that they had normal face recognition abilities, they were run with the famous face test and the sequential face-matching test discussed above. All performed normally on both tests, and all performed better with upright face matching than inverted face matching (see Figure 2). This upright advantage in the context of normal performance indicates that they have normal face expertise.

### Greeble Training Results

The design of our training program was almost identical to that used in a recent paper (Gauthier and Tarr, 2002) and was very similar to that used in past training experiments (Gauthier and Tarr, 1997; Gauthier et al., 1998). The identities of five individual greebles were presented in the first session, and five additional identities were presented in each of the next three sessions. Thus, by the fourth session subjects had been introduced to the identities of 20 different greeble individuals. There were a total of eight sessions, and no greebles were introduced in the final four sessions. Individuals in the same family share the same general body shape, and familiarization with all five families takes place in the first sessions. Knowledge of the greebles was assessed with two types of test trials. On verification trials, a label is briefly presented (either an individual name or a family name) and it is followed by a greeble. The greeble remained visible until subjects indicated whether the label and the greeble were consistent. On naming trials, subjects were presented with a greeble and identified it by pressing the letter key corresponding to the first letter of the greeble's name.

The rapid expertise hypothesis predicts that Edward's performance will be comparable to the controls in the early part of the training when the control subjects have not developed expertise. However, in the later sessions when the controls have developed expertise, it predicts that Edward's performance will become progressively worse compared to the controls. Figure 3 displays accuracy with the greebles for the control subjects and Edward. Because greebles are added during the early sessions of training, we have scaled the figures displaying the naming accuracy and individual verification accuracy in the same manner for each subject to reflect the number of known greebles in each session (5, 10, 15, 20). For example, in the first session, we divided the percent correct for each subject by 4 so that 100% correct for the first session was set at 25% of total percent correct. Figure 3A shows scaled percent correct for the naming trials. Contrary to the predictions of the rapid expertise hypothesis, Edward is performing as well as the four best performing control subjects and substantially better than two of the more poorly performing controls. Similarly, Figure 3B shows that his performance is also normal on the individual verification trials. Finally, Figure 3C shows that he performs very well on the family naming trials.

Figure 4 shows his mean response times for the three

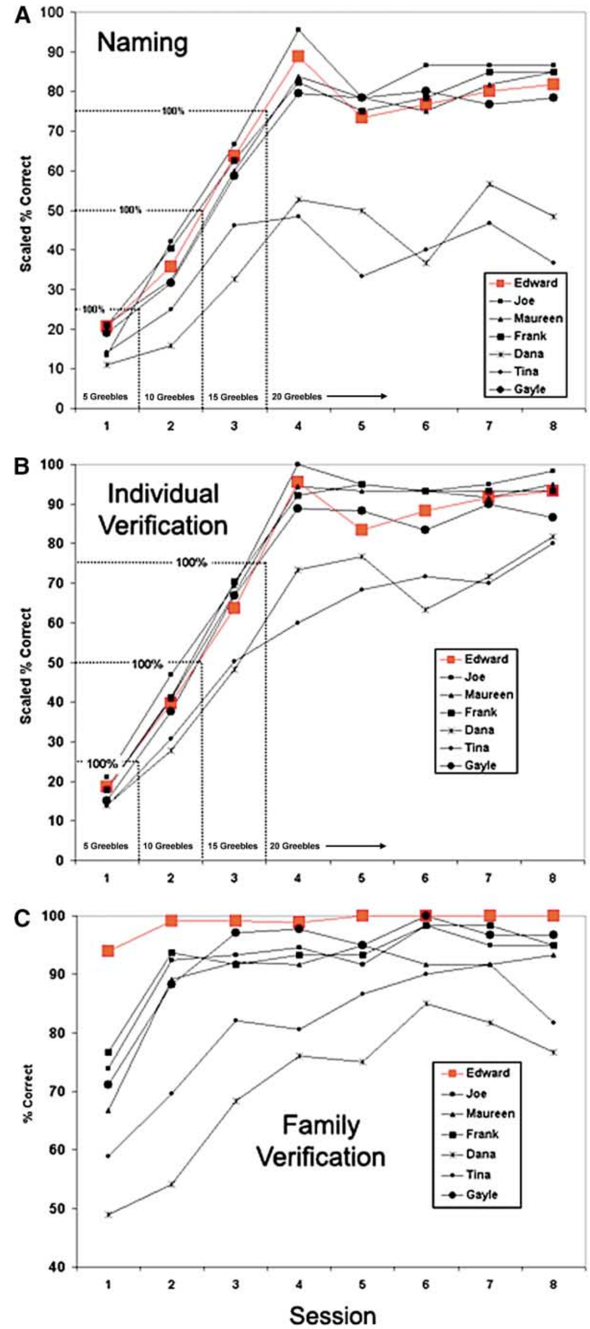


Figure 3. Greeble Training Accuracy Results

Percent correct for the three types of trials assessing greeble knowledge.

(A and B) For the naming trials (A) and the individual verification trials (B), we have scaled the scores to reflect the number of greebles with names at each point in the training. For example, subjects had only been introduced to 5 of the 20 greebles in session 1, so we divided their percent correct by 4 and placed the 100% level for session 1 at 25% of the total percent correct.

(C) Percent correct for the family verification trials.

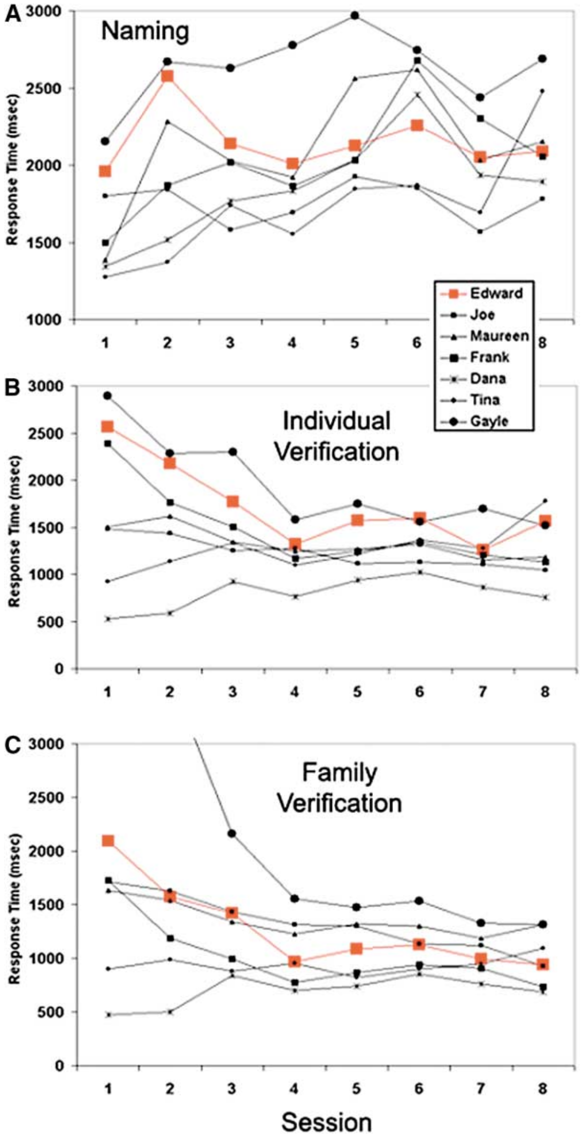


Figure 4. Greeble Training Response Times

Response times in ms for the three types of trials: (A) naming RT, (B) individual verification RT, and (C) family verification RT. Response times are reported in geometric means. Geometric means were used in past greeble papers, because they are less susceptible to outliers.

trial types over the eight sessions, and he is in the normal range here as well. Thus, speed-accuracy trade-offs cannot explain his normal accuracy. The percent correct for the middle-aged control subjects is similar to that for undergraduate subjects in previous experiments (Gauthier and Tarr, 1997, 2002; Gauthier et al., 1998) as well for the undergraduates who served as our pilot subjects. As expected, the response times were slower for the middle-aged subjects than for the undergraduates used in previous experiments and our pilot experiments.

## Discussion

Edward's normal performance in the greeble training would seem to provide a clear refutation of the rapid expertise hypothesis. He presents an extreme example of face recognition impairments, and the selectivity of his face deficits is as pronounced as any reported. His normal performance with greebles is wholly inconsistent with the view that his deficit is caused by a deficit to domain-general expertise mechanisms that are engaged after only hours of training.

There are two ways to interpret Edward's performance relative to the control subjects. One possibility is that Edward and the controls developed greeble expertise, because both have whatever mechanisms are necessary for rapid expertise acquisition. On this account, these rapid expertise mechanisms are separate from the mechanisms used for face recognition and those used for nonexpert object recognition. However, we believe that the more fundamental issue as to whether greeble training leads to qualitatively different (i.e., expert) processing needs to be raised. If greeble training does not produce expertise, then Edward and the control subjects simply relied on ordinary object recognition mechanisms to recognize the greebles. We favor this second interpretation.

As mentioned above, it has been claimed that greeble training leads to perceptual and neural effects that are similar to effects seen almost exclusively with faces (Gauthier and Tarr, 1997, 2002; Gauthier et al., 1998). A close review of this evidence, however, does not support these claims (McKone and Kanwisher, 2004). The presence of three perceptual effects thought to be face specific has been assessed after greeble training, and these subjects have not shown face-like effects (Gauthier and Tarr, 1997, 2002; Gauthier et al., 1998). There is no evidence that greeble training leads to face-like inversion effects nor is there clear evidence for the transfer of expertise to novel sets of greebles (Gauthier et al., 1998). The neural evidence for face-like processing after greeble training is similarly unpersuasive. There are no demonstrations that training leads to increased activation in the fusiform gyrus during greeble viewing (McKone and Kanwisher, 2004), and ERP studies have shown that greeble training leads to left-lateralized markers rather than the right-lateralized markers seen with faces (Rossion et al., 2002).

Thus, it appears most likely that, like past greeble subjects, neither Edward nor the controls acquired expertise during training but rather simply became familiar with the greeble-name pairs and the task demands. In light of past suggestions that expertise requires roughly ten years of experience (Carey, 1992), it is not surprising that ten hours of training does not produce expertise. Because arguments for the rapid conception of expertise have claimed support solely from experiments involving greeble training, there is currently no evidence that recognition mechanisms like those used with upright faces can be activated or assembled after only hours of experience with a nonface object class. This is not to deny that the visual system can be tuned over short time scales, but only that processing like that seen with faces does not emerge over such time scales.

Edward's results also provide additional evidence supporting the double dissociation between face and object processing provided by neuropsychological cases (Farah et al., 1995; McNeil and Warrington, 1993; Moscovitch et al., 1997; Nunn et al., 2001). This dissociation could be accounted for by face-specific mechanisms or expertise mechanisms like that proposed by the "extended" conception of expertise. Our results do not bear on the merits of either hypothesis, but past cases suggest that face expertise and real-world nonface expertise are dissociable (Moscovitch et al., 1997; Sergent and Signoret, 1992). Future investigations focused on the existence of this dissociation should provide a means to more precisely characterize the nature of the mechanisms performing face recognition.

## Experimental Procedures

### Materials

A set of 30 photorealistically rendered, grayscale greebles were used. The greebles were approximately 11 cm high and 7 cm at their widest. At our viewing distance of 60 cm, they subtended about $10.5^\circ \times 6.7^\circ$ of visual angle.

### Procedure

Each subject participated in eight training sessions. The first four training sessions lasted approximately 1 hr each while the remaining four sessions lasted approximately 15 min each. The five family names were introduced in the first session by presenting greebles accompanied by their family label. Following this, we also presented an image for 20 s that showed two examples from each family so that subjects could view the similarities and differences between the families. Individual names for five greebles were learned in each of the first four sessions so that a total of 20 individual names were learned. Each individual name began with a different letter. Subjects learned the names by viewing the greeble accompanied by its name and then practiced naming it by pressing the key corresponding to its first name. Following each practice trial, subjects received a feedback trial displaying the correct name.

Following the introductory phase, subjects were tested with blocks of verification trials and naming trials. The number of test trials in the first four sessions ranged from 495 to 680 and there were 180 trials in each of the final four sessions. On verification trials, subjects were presented with a label (either a family name or an individual name) for 1000 ms, and after a 200 ms interval a greeble was presented. Subjects indicated with a key press whether the label and the greeble were consistent. On some verification trials, a label reading "No Name" was presented, and subjects indicated whether they had learned a name for that greeble. On naming trials, subjects were presented with a greeble and indicated the greeble's first name with the first letter of its name. When greebles without names were presented, the correct answer was a space bar press.

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