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Enhanced Facial Discrimination: Effects of Experience With American Sign Language

Jeffrey G. Bettger
San Francisco State University

Karen Emmorey
Stephen H. McCullough
Ursula Bellugi
The Salk Institute for Biological Studies

On-line comprehension of American Sign Language (ASL) requires rapid discrimination of linguistic facial expressions. We hypothesized that ASL signers' experience discriminating linguistic facial expressions might lead to enhanced performance for discriminating among different faces. Five experiments are reported that investigate signers' and nonsigners' ability to discriminate human faces photographed under different conditions of orientation and lighting (the Benton Test of Facial Recognition). The results showed that deaf signers performed significantly better than hearing nonsigners. Hearing native signers (born to deaf parents) also performed better than hearing nonsigners, suggesting that the enhanced performance of deaf signers is linked to experience with ASL rather than to auditory deprivation. Deaf signers who acquired ASL in early adulthood did not differ from native signers, which suggests that there is no "critical period" during which signers must be exposed to ASL in order to exhibit enhanced face discrimination abilities. When the faces were inverted, signing and nonsigning groups did not differ in performance. This pattern of results suggests that experience with sign language affects mechanisms specific to face processing and does not produce a general enhancement of visual discrimination. Finally, a similar pattern of results was found with signing and nonsigning children, 6–9 years old. Overall, the results suggest that the brain mechanisms responsible for face processing are somewhat plastic and can be affected by experience. We discuss implications of these results for the relation between language and cognition.

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A common yet difficult task required of the visual system is discriminating between and recognizing human faces. For example, we often must pick out the face of a friend in a crowd, a difficult task because all people have the same general facial features and configuration—two eyes above a nose above a mouth. Some studies have suggested that our expertise in human face recognition is due to specialized brain mechanisms (e.g., Yin, 1969; Farah, 1996). In the studies presented here, we investigate whether experience can alter certain face-processing abilities and whether such effects are seen early in development or only in adulthood. Finding effects of experience will suggest that the brain mechanisms responsible for human face processing are relatively plastic and can be affected by environmental experience with faces. But how do we test for differences in experience with human faces? Some researchers have even suggested that the uniqueness of face-processing mechanisms arises because we are all experts at human face perception. However, there is reason to suspect that one group of people may acquire additional "expertise" due to their particular experience with the human face: deaf people who use American Sign Language (ASL).

A unique and modality-specific aspect of ASL grammar is the use of the face as a linguistic marker.

Different facial expressions serve to mark different lexical and syntactic structures, such as wh-questions (e.g., what, where, when), relative clauses, conditionals, adverbials, and topics (Baker-Shenk, 1983; Liddell, 1980; Reilly, McIntire, & Bellugi, 1990a). These facial expressions differ from emotional expressions in their scope and timing and in the facial muscles used (Reilly, McIntire, & Bellugi, 1990b). Grammatical facial expressions have a clear onset and offset and are coordinated with specific parts of the signed sentence. These expressions are critical for interpreting the syntactic structure of many ASL sentences. For example, restrictive relative clauses are indicated by raised eyebrows, a slightly lifted upper lip, and a backward tilt of the head. When this combination of head and facial features occurs, the co-occurring lexical items are interpreted as constituting a relative clause (Liddell, 1980). Conditional clauses are signaled by raised eyebrows, a head tilt to the side, and a slight forward movement of the shoulders. Again, the onset and offset of these features signal the scope of the conditional clause and distinguish this clause type from a conjoined main clause. Facial behaviors also constitute adverbials that appear in predicates and carry different specific meanings. For example, the facial expression "mm" (lips pressed together and protruded) indicates an action done effortlessly, whereas the facial expression "th" (tongue protrudes between the teeth) means "awkwardly" or "carelessly." These two facial expressions accompanying the same verb (e.g., DRIVE) convey quite different meanings ("drive effortlessly" or "drive carelessly"). Finally, facial expressions operate at a referential discourse level to convey "shifted attribution of expressive elements" (Engberg-Pedersen, 1993) and function to convey character point of view. In this case, facial expressions convey affective information representing the perspective of a particular discourse referent, similar to the use of "free indirect style" in spoken languages.

It is clear from the preceding description that ASL signers must be able to quickly identify and discriminate between different linguistic and affective facial expressions in order to process and interpret signed sentences. Facial expressions signal syntactic and semantic structure at lexical, syntactic, and discourse levels. In this article, we investigate how experience discriminating linguistic facial expressions, as is necessary in ASL, affects the ability to discriminate faces in a nonlinguistic domain.

In the five experiments reported here, we used the Benton Test of Facial Recognition (Benton, Hamsher, Varney, & Spreen, 1983) For this test, subjects are required to detect a target face from within a set of six similar-looking faces (see Figure 1). We consider this test to be actually a measure of face *discrimination,* not recognition, because subjects must discriminate among a group of faces presented on the same page rather than recognize a remembered target face. Therefore, we will refer to this test as the "Benton Faces Test" rather than by its formal name. We chose this test as a measure of face-processing ability because it is relatively difficult (and thus may be sensitive enough to reveal differences between subject groups), and we hypothesized that the ability to distinguish between different facial *expressions* (a task that ASL signers must do quickly and frequently) may lead to an enhancement in the ability to distinguish between the different *faces.* We predicted that groups of deaf signers will perform better than groups of hearing nonsigners. Experiments 1–3 compare the performance of adults, and experiments 4 and 5 compare the performance of children.

Experiment 1: Method

In this experiment, we provide the foundation for our studies of the effects of experience on behavior. We start with the basic question: do behavioral differences on a facial discrimination test exist between deaf people who use ASL and hearing people who do not?

Subjects. Sixteen hearing adults (mean age = 22 years) and sixteen deaf adults (mean age = 33 years) participated in the experiment. The deaf subjects were either recruited from the Fremont, California, community and tested at the California School for the Deaf in Fremont or recruited and tested at a California Association for the Deaf meeting in San Diego. All deaf subjects were born to deaf parents (DD for "deaf with deaf parents") and acquired ASL as their first language. These subjects reported that ASL was their primary and preferred language. Hearing subjects (HH for "hearing with hearing parents") were recruited from the Riverside, California, community and were tested at the University of California Riverside. This group had no signing experience.

Materials and procedures. In the Benton Faces Test, a booklet of photographs is presented to the subject. For each of the 22 trials in the long-form version of the test, a photograph of a target face is shown at the top of the page. Below this target photograph are six choice photographs. To answer correctly, a subject must point to the choice picture that is the same person as shown in the target photograph. The remaining choices are distracter photographs of people who look similar to the target person in overall appearance (see Figure 1).

The 22 trials are divided into three conditions. For the first six test items (the front condition), all of the faces are looking straight ahead. Subjects were informed that only one of the six choice photographs is the same person shown in the target photograph. For the second and third conditions of the test (the profile and shadow conditions), subjects were informed that three of the six choice photographs are the same person shown in the target photograph and that all three must be correctly identified. In the profile condition, all six choice photographs show the faces from a side view. In the shadow condition, all six choice photographs show the faces looking forward but are taken under lighting conditions that produce shadows across portions of the faces. The 22 trials in the long-form version of the test consists of six front trials (one answer each), followed by eight profile view trials (three answers each) intermixed with eight shadow trials (three answers each), producing a total of 54 possible correct answers. Subjects were informed that no time limit existed for this task.

Experiment 1: Results and Discussion

As suggested by Benton et al. (1983), each of the 54 total responses produced from the 22 trials was scored separately as correct or incorrect. Percentage correct was computed to be comparable with scores obtained from the short-form version of the test (13 trials producing 27 possible correct) used in studies 4 and 5.

The average correct percentages for the deaf and hearing groups are shown in Table 1. We found that deaf ASL signers performed significantly better overall than hearing nonsigning adults (see Table 1). Given the overall group difference, we next computed planned comparisons for each of the three conditions of the test (front, profile, shadow) to determine whether any one stimulus condition most differentiates the groups.

Significant group differences were found for those trials in the shadow condition. Note that the primary difference between the shadow condition and the other two conditions is that many individual features in the

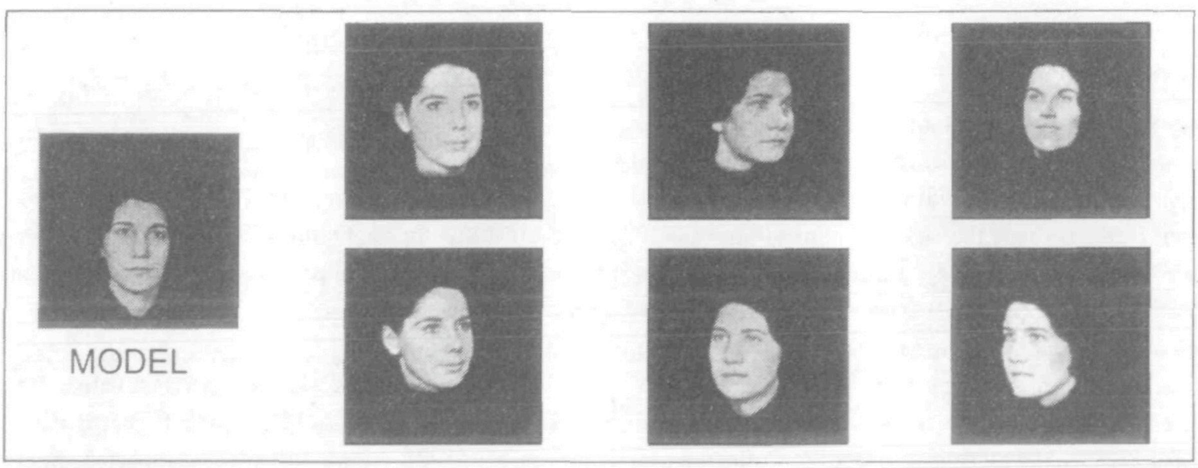

Figure 1 Example stimulus from the Benton Faces Test. The model face is the same face as the top middle, bottom middle, and bottom right face. This example is from the profile condition.

Table 1 Mean percentage correct for deaf and hearing adults on the Benton facial discrimination task

	Subject group		
Conditions	DD	HH	F value
Total	87.4	81.7	$F(1,30) = 5.29, p < .05$
Breakdown by view			
Front	100	99	$F(1,30) < 1$, ns
Profile	91.6	86.5	$F(1,30) < 1$, ns
Shadow	73.3	63.9	$F(1,30) = 5.98, p < .05$

shadow stimuli are obscured. Even though the profile view provides a different perspective, each type of feature of the face (e.g., eyes, eyebrows, ears) is visible. Apparently, all subjects were at ceiling on the front condition.

The results from this study provide the foundation and starting point for our exploration into the performance differences found when testing deaf adults and hearing adults on a facial discrimination task. Deaf signers were significantly more accurate in detecting a target face from among a set of distracters, particularly, those faces partially obscured by shadows.

However, the two groups differ in two important ways: language modality (a visual-spatial language compared with an auditory-spoken language) and auditory experience (deafness compared to normal hearing). In experiment 2, we attempt to tease apart the effects of language and sensory experience.

Experiment 2: Linguistic Versus Sensory Experience

It is possible that the advantage of deaf subjects in experiment 1 is not due to experience processing facial expressions in ASL, but rather to auditory deprivation from birth. Perhaps the lack of auditory input boosts face discrimination skills because deaf subjects depennd more on the visual sensory system for obtaining information. Exposure to a visual-spatial language, such as ASL, may be irrelevant. To investigate the degree to which *language exposure* versus *auditory deprivation* is associated with enhanced face discrimination, we conducted an experiment that included two additional groups of subjects: hearing subjects who have deaf parents and who are native signers (HD subjects) and deaf subjects with hearing parents who acquired ASL late (DH subjects).

HD subjects acquire ASL as a first language from their deaf parents, but crucially, these subjects can hear. If enhanced face discrimination is due to auditory deprivation from birth, then hearing native signers should show a pattern of results similar to those for hearing nonsigners. On the other hand, if this increased ability is due to experience processing ASL, then the hearing native signers should show the same enhanced performance as do the deaf native signers.

DH subjects are deaf, have hearing parents, and were not exposed to ASL until late childhood or early adulthood. By comparing the performance of these subjects with the DD and HD subjects, we can investigate whether there might be a "critical period" for the observed enhancement. That is, if DH subjects perform like hearing nonsigners, we can suggest that early exposure to ASL is necessary for the enhancement effect.

Experiment 2: Method

Subjects. All subjects were tested at the National Technical Institute for the Deaf (NTID) in Rochester, New York. All subjects were paid for their participation in the experiment. Further group details are given below.

DD group (deaf subjects with deaf parents; native deaf ASL signers). Eight NTID students participated (mean age = 21 years). All subjects reported themselves to be deaf from birth, with a current Pure Tone Average (PTA) hearing level of above 90 dB. All subjects learned ASL from their parents and relatives from birth and were rated at the highest level on an ASL proficiency test administered upon entering NTID.

DH group (deaf subjects with hearing parents; late ASL signers). Eight NTID students participated (mean age = 24 years). All subjects reported themselves to be deaf from birth, with a current average PTA hearing level of above 87 dB, except for one subject at 83 dB. Because most of these subjects had previously attended schools that emphasized lip-reading and oral skills, they reported having only minimal signing experience before entering NTID. The average reported amount of signing experience was three years.

HD group (hearing subjects with deaf parents; native ASL signers). Eight hearing subjects who have deaf parents participated in the experiment (mean age = 42 years, ranging from 25 to 60 years old). All subjects had normal hearing. At the time of this experiment, three of these subjects were employed as ASL interpreters, and the other five were employed as instructors or administrators at NTID. All eight subjects in this group learned ASL from birth from their deaf parents and other relatives.

HH group (hearing subjects with hearing parents; nonsigners). Eight hearing monolingual students at the Rochester Institute of Technology participated (mean age = 22 years). All subjects had normal hearing and had no signing skills.

Materials and procedures. All materials and procedures were identical to those used in experiment 1.

Experiment 2: Results and Discussion

The mean percentage correct for each subject group is presented in Table 2. Using a one-factor analysis of variance (ANOVA), we find that the groups were significantly different from each other. Based on the overall group difference, multiple planned pairwise comparisons show that both the DD and HD groups scored significantly higher than the HH group ($p < .02$) and the DH group scored higher than the HH group, although the difference fell just short of significance ($F[1,15] = 4.46$, $p = .05$). The DD, DH, and HD did not significantly differ from each other.

Table 2 Mean percentage correct for each adult group on the Benton facial discrimination task

	Subject group				
Conditions	DD	HD	DH	HH	*F* value
Total	90.4	89.6	87.3	79.3	$F(3,31) = 5.01, p < .01$
Breakdown by view					
Front	95.8	100	100	100	$F(3,31) = 2.33$, ns
Profile	96.9	94.3	91.7	85.4	$F(3,31) = 2.65$, ns
Shadow	82.3	81.8	79.7	68.2	$F(3,31) = 4.40, p < .02$

Based on the findings of experiment 1, we found that the shadow condition once again provided the greatest group difference. However, the same pattern of group performance is found for the profile view (i.e., DD highest, HH lowest), although this difference did not reach significance. All groups were at ceiling on the front view condition.

This experiment replicates and extends the findings of experiment 1. As in experiment 1, deaf native signers performed significantly better on the Benton Faces Test than hearing subjects with no signing experience. Furthermore, hearing subjects who were native signers also performed significantly better than nonsigning subjects, indicating that experience with ASL, rather than auditory deprivation, leads to an enhanced ability to discriminate among faces. The performance of deaf signers who acquired ASL in early adulthood did not differ from that of native signers, and their performance was also better than that of the nonsigning hearing group. This result indicates that there is no "critical period" during which signers must be exposed to ASL in order to exhibit enhanced face discrimination abilities. The observed enhancement effect does not appear to be tied to early exposure to ASL.

Experiment 3: Inverted Faces

It has long been known that inverting faces has a negative effect on facial recognition tasks (Arnheim, 1954). Furthermore, while inversion does affect recognition of other types of familiar mono-oriented objects (such as houses, airplanes, or costumes), inversion disproportionately impairs the recognition of faces (Yin 1969, 1970). This "inversion effect" has been interpreted as indicating that unique mechanisms underlying face processing are sensitive to changes in orientation. However, Diamond and Carey (1986) suggested that the inversion effect with face recognition is actually the result of perceptual experience. To support their alternative hypothesis, they presented inverted pictures of dogs to two groups: dog breeders and nonexperts. The dog breeders are assumed to have more extensive perceptual experience with a specific dog breed, and, according to the hypothesis, the experts should be more disrupted in comparison to the nonexperts when the images are presented in a noncanonical orientation. The data confirmed the hypothesis; dog breeders exhibited a larger inversion effect compared to subjects who were not experts. That is, the group of dog breeders did more poorly recognizing inverted dog faces than did the nonexperts, suggesting a relationship between the inversion effect and expertise. These data provide the rationale for our next study: do ASL signers, whose language requires extensive use of specific, facial expressions to convey linguistic information, have a larger inversion effect (i.e., perform more poorly when discriminating inverted faces compared to nonsigners)?

Experiment 3: Method

Subjects. Seventeen deaf college students and 20 hearing nonsigning college students participated in the experiment. All deaf subjects had deaf parents and were exposed to ASL from birth. Deaf subjects were paid for their participation and were tested at Gallaudet University in Washington, D.C. Hearing subjects from the University of California San Diego were either paid or received course credit for their participation and were tested at the Salk Institute in La Jolla, California.

Materials and procedure. Each subject was given the upright and the inverted version of the Benton Faces Test. As in experiments 1 and 2, the long form of each test was used. Half of the subjects in each group received the upright test first; the other half of the subjects received the inverted test first. For the inverted form of the test, the target face was upright, and the response faces were all upside-down.

Experiment 3: Results and Discussion

A repeated measures ANOVA with the total score revealed that all subjects performed better on the upright test than on the inverted test ($F[1,35] = 65.38$, $p < .01$). There was no main effect of subject group. Importantly, the interaction between test type and subject group was significant ($F[1,35] = 12.86$, $p < .01$). Results from the upright test are shown in Table 3. Similar to experiments 1 and 2, DD subjects scored higher than hearing nonsigners, although the difference in total score did not reach significance this time. However, we did find that native signers scored significantly higher than hearing nonsigners on the critical shadow condition.

Results from the inverted condition are shown in Table 4. In the inverted condition, for the first time, we find that the deaf signers actually have a lower group average than the hearing subjects on each component of the test, as well as on the overall score. Of particular interest is the data from the front view component of the test. Whereas both groups were at ceiling on the

Table 3 Mean percentage correct for deaf and hearing adults on the Benton upright facial discrimination task

	Subject group		
Conditions	DD	HH	*F* value
Total	83.55	80.09	$F(1,35) < 1$, ns
Breakdown by view			
Front view	99	98.33	$F(1,35) < 1$, ns
Profile view	87.5	86.25	$F(1,35) < 1$, ns
Shadow view	75.75	69.38	$F(1,35) = 4.59$, $p < .05$

Table 4 Mean percentage correct for deaf and hearing adults on the Benton inverted facial discrimination task

	Subject group		
Condition	DD	HH	*F* value
Total	71	75.1	$F(1,35) = 2.267$, ns
Breakdown by view			
Front view	85.3	99.2	$F(1,35) = 7.76$, $p < .01$
Profile view	78.9	81.5	$F(1,35) = 1.04$, ns
Shadow view	60.8	62.7	$F(1,35) < 1$, ns

upright version of the front view, the deaf signers performed significantly lower than did the hearing nonsigners when these stimuli were inverted.

The results provide some evidence for an expertise effect for ASL signers for face processing. When faces were inverted and presented in the front view condition, ASL signers scored significantly lower than hearing nonsigners. This pattern of results is similar to that of Diamond and Carey (1986), who found that expert dog breeders showed worse performance under inversion than novices. Our finding of an expertise effect for ASL signers supports the hypothesis that the enhanced performance on discriminating canonical upright faces is due to signers' unique experience with the human face.

In addition, Farah, Wilson, Drain, and Tanaka (1995) have recently suggested that the hypothesized brain mechanisms responsible for human face processing are not utilized when faces are turned upside down. Farah et al. propose that face perception systems are specific to upright faces. Since ASL signers did not perform better than hearing nonsigners when faces were inverted, we argue that experience with sign language affects only mechanisms specific to face processing. Experience with ASL does not produce a general enhancement of discrimination abilities (even when the stimuli are faces).

Experiment 4: Children, Upright Faces

In this study, we begin to investigate how and when facial discrimination enhancement develops. By the time native signing children are 9 or 10 years old, they have mastered many of the linguistic facial expressions of ASL (Reilly et al., 1990a, 1990b). We investigate whether children who have had exposure to ASL from birth show the same enhancement as do adults. Have these children had enough experience interpreting ASL facial expressions to produce an effect on nonlinguistic face discrimination skill? What about the deaf children who have had delayed exposure to ASL? Deaf children with hearing parents who are exposed to ASL late may not have yet mastered these linguistic markers since they generally show delays in the acquisition of numerous ASL grammatical structures (Bettger, Klima, Ewan, & Smith, 1995; Galvan, 1989). To investigate these issues, the Benton Faces Test was given to DD (native signers), DH (late signers), and to HH (nonsigners).

Experiment 4: Method

Subjects. Thirty-six DD and 17 DH children from the California School for the Deaf in Fremont, California, were tested. Twenty HH children from Lafayette Elementary school in San Diego, California, and from the Riverside, California, community were tested. All children were between the ages of 6 and 9 years old. Average age for the three groups at time of test was 7;7, 7;2, and 7;5 years old for the DD, DH, and HH groups, respectively.

Materials and procedures. Subjects were given a reduced version of the Benton Faces Test. The short-form version consists of the first 13 trials of the long-form version (i.e., six front, four profile, three shadow). This combination of trials produces a total of 27 possible correct answers (as opposed to 54 possible in the long-form version). All deaf children were tested by a deaf researcher (native signer) using ASL, and all hearing children were tested by a hearing researcher using English.

Experiment 4: Results and Discussion

The ANOVA results and test scores are shown in Table 5. Planned pairwise comparisons revealed that the DD children scored significantly higher than both the DH and HH children for the total and profile scores. The DD children scored significantly higher than only the HH children for the shadow scores. The DH and HH

Table 5 Children's mean percentage correct on the Benton upright facial discrimination task

	Subject group			
Condition	DD	DH	HH	*F* value
Total	75.31	65.14	66.85	$F(2,70) = 8.66, p < .01$
Breakdown by view				
Front	92.13	83.33	87.5	$F(2,70) = 1.54$, ns
Profile	77.08	60.29	67.5	$F(2,70) = 7.32, p < .01$
Shadow	61.73	59.48	52.22	$F(2,70) = 3.84, p = .03$

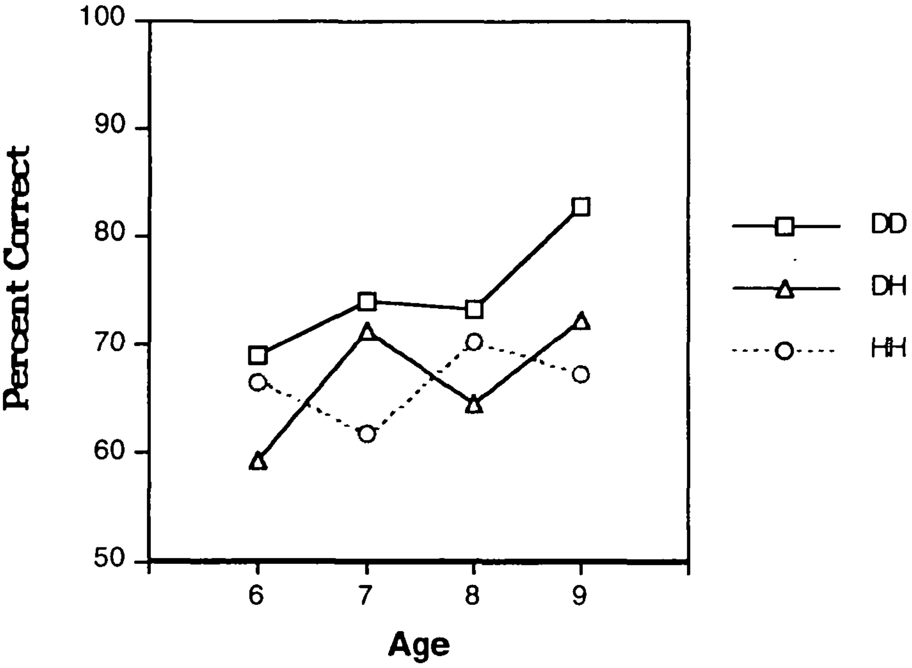

Figure 2 Performance on the upright version of the Benton Faces Test by deaf children exposed to ASL from birth by deaf parents (DD), deaf children with hearing parents exposed to ASL later in childhood (DH), and hearing children who have no signing experience (HH).

children did not differ significantly for total score or for any of the component scores.

Figure 2 plots the total score for each group by age. Children tend to get better on the test with age. Importantly, at each age level, the DD children scored above both the HH and DH children.

These data show that the enhancement of facial discrimination we found with native adult signers is also apparent in deaf children ages 6–9 years who have been exposed to ASL from birth. In contrast to experiment 2 (adults), we found that deaf children with hearing parents performed more like nonsigning children than like native signing children. Differences between DD and DH children may be related to the fact that DD children are not only exposed to ASL from birth, but are also more likely to be exposed to a richer and more complete version of ASL that more frequently includes the use of linguistically meaningful facial expressions. DH children may not have been exposed to ASL long enough or with enough consistency to affect their nonlinguistic face discrimination skills. However, the results from experiment 2 suggest that by adulthood, these children will have been exposed to ASL long enough to produce enhanced face-processing abilities.

Experiment 5: Children, Inverted Faces

In this experiment, we investigated the inversion effect for faces with DD and DH and HH children. Experiment 4 showed that native signing children were superior on the Benton Faces Test when the faces were presented in their canonical orientation. If this enhancement is due to face-specific processing mechanisms and if DD children's enhancement is due to their experience with ASL, then we predict that under inversion, DD children will perform similarly to DH and HH children, or perform more poorly under inversion due to the expertise effect.

Experiment 5: Method

Subjects. Thirty-one DD and 27 DH children from the California School for the Deaf at Fremont, California, were tested. Forty-two HH children from Lafayette Elementary School in San Diego, California, were likewise tested. All subjects were between the ages of 6 and 9 years old. Average age for the three groups at time of test was 7;8, 7;10, and 7;7 years old for the DD, DH, and HH groups, respectively.

Procedures. All procedures for the inverted version of this test were the same as for the upright version given to children in experiment 4.

Experiment 5: Results and Discussion

The ANOVA results and test scores are shown in Table 6. The total score data are plotted by age in Figure 3. The three groups did not differ significantly from each other on total score or on any of the three components (i.e., front, profile, or shadow) of the inverted faces test.

All three groups had very similar scores. As with the adults in experiment 3, the DD children had generally lower scores than the HH children, but the differences in scores did not reach significance on any comparison. The DD children may not have had enough exposure to ASL to exhibit an expertise effect (i.e., worse performance under inversion compared to nonsigners). Nevertheless, these results again suggest that enhanced discrimination ability is specific to face processing since face-processing mechanisms are argued to operate only for the recognition of canonically oriented faces (Farah et al., 1995). Since these mechanisms are not called into play for inverted faces, native signing children and adults are not superior to nonsigning subjects.

Table 6 Children's mean percentage correct on the Benton inverted facial discrimination task

	Subject group			
Condition	DD	DH	HH	*F* value
Total	57.88	58.67	58.47	$F(2,97) < 1$, ns
Breakdown by view				
Front	59.14	61.73	59.12	$F(2,97) < 1$, ns
Profile	62.9	62.86	61.77	$F(2,97) < 1$, ns
Shadow	50.53	51.13	53.70	$F(2,97) < 1$, ns

General Discussion

ASL contains linguistic markers expressed by the face. We hypothesized that signers' extensive experience attending to and processing linguistic facial expression might lead to a general enhancement of face discrimination ability. Five experiments, in three different states, investigated signers' and nonsigners' ability to discriminate human faces photographed under different conditions of orientation and lighting, as measured by the Benton Faces Test. The results showed that adult deaf native signers were significantly more accurate than hearing adults who had no sign language ex-

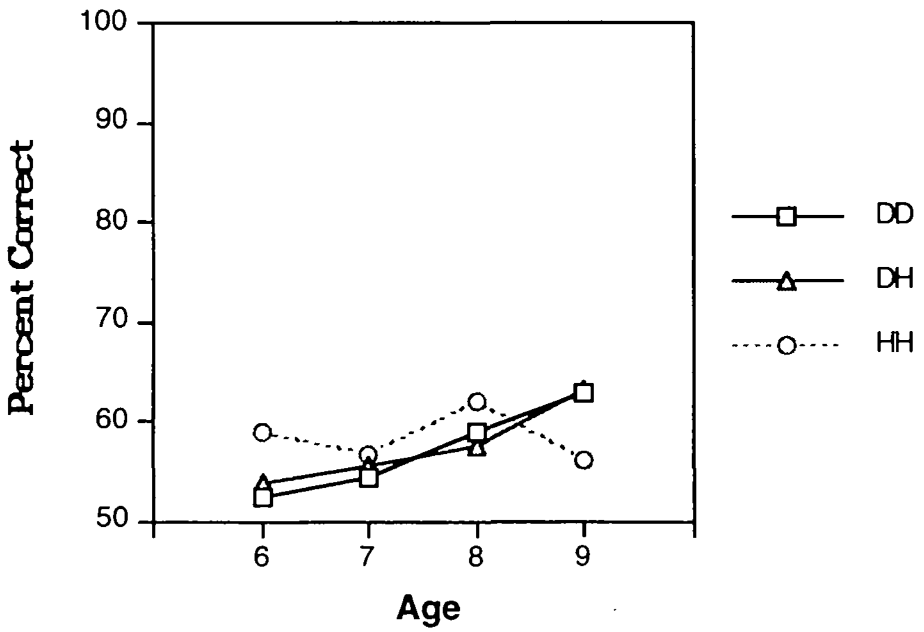

Figure 3 Performance on the inverted version of the Benton Faces Test by deaf children exposed to ASL from birth by deaf parents (DD), deaf children with hearing parents exposed to ASL later in childhood (DH), and hearing children who have no signing experience (HH).

perience. For all experiments (except those with inverted faces), the difference between signing and nonsigning groups was most evident for trials in which facial features were obscured by shadows. For these trials, an effective strategy is to match individual features of the target face with the visible features of the choice faces. Such a strategy may not be necessary for the front and profile conditions, in which each type of facial feature is visible. Recently, McCullough and Emmorey (1997) have found evidence that ASL signers may be particularly adept at discriminating individual facial features. If the shadow condition draws more on mechanisms involved in featural processing (rather than gestalt processes), this might explain why signers were particularly accurate in this condition. Another possibility is that level of difficulty is driving this pattern of results. The shadow condition was most difficult for all subjects (see Tables 1–6). Enhanced discrimination ability may only emerge when a certain level of difficulty is attained. Evidence for this possibility can be found in the data from the children. Children performed worse than adults, indicating that the task was more difficult for them (compare Table 5 with Tables 1–3). In contrast to the adults, native signing children were significantly more accurate than hearing nonsigning children on *both* the profile and shadow conditions. For the children, the level of difficulty may have been high enough for significant differences in face discrimination skill to emerge.

The results of experiment 2 revealed that hearing native signers performed significantly better than hearing nonsigners. Furthermore, Parasnis, Samar, Sathe, and Bettger (1996) found that "oral" deaf children who had no exposure to sign language performed similarly to hearing nonsigning children on the Benton Faces Test. Together these results strongly suggest that enhanced face discrimination skill is due to knowledge and use of sign language, rather than to auditory deprivation per se. Further evidence that ASL signers are "experts" at face discrimination was found in experiment 3, in which subjects were presented with inverted faces. Like Diamond and Carey (1986), we found evidence for an "expertise effect" in which experts are more sensitive to inversion than novices. ASL signers performed more poorly than nonsigners when faces were inverted. This finding again supports the hypothesis that environmental experience is driving the enhancement effect we observe with canonically oriented faces. Furthermore, Farah et al. (1995) present neuropsychological data to argue that brain mechanisms specific to faces do not operate when faces are inverted. Thus, we argue that since ASL signers (both children and adults) did not outperform hearing nonsigners for inverted faces, the enhancement that we observed for canonical upright faces is not a general enhancement of visual discrimination skill, but is specific to face processing.

The results with deaf children indicated that the effects of sign language experience can be observed as early as 6 years of age—but only when children have been exposed to ASL from birth. Deaf children with delayed exposure to ASL did not show the same performance enhancement as did native signing children. However, exposure to ASL during childhood does not appear to be critical since deaf adults who acquired ASL in adulthood exhibited enhanced face discrimination abilities. Similarly, other researchers are discovering that signers who acquire ASL later in childhood (or even in early adulthood) exhibit enhanced cognitive processing skills similar to those of native signers, although usually the effect is not quite as strong for the nonnative (late-exposed) signers (see Emmorey [in press] for a review of studies examining the impact of sign language use on visual-spatial cognition). For example, Emmorey, Kosslyn, and Bellugi (1993) found that both native and nonnative signers were faster in a mental rotation task than hearing nonsigners, but the native signers were more accurate than both groups. Talbot and Haude (1993) found that hearing adults who had six years of experience with ASL outperformed hearing nonsigners on a similar mental rotation task. Bettger (1992) found that deaf native, deaf nonnative, and hearing native signers were all more accurate than hearing nonsigners on a different mental rotation task and on a movement perception task. Thus, at least for some cognitive tasks, we may find that it is the consistency and the duration of exposure to sign language that lead to changes in cognitive abilities, rather than the timing of that exposure during development.

Overall, the data point to a direct connection between language and a nonlinguistic domain of cognition: discriminating unfamiliar faces. One might ask whether the results are evidence of a "Whorfian" effect. Do the findings support the hypothesis that the language one uses (ASL or English) has a differential effect on how one thinks? Thus far, the data do not indicate that ASL signers are actually processing faces differently than nonsigners or that they mentally represent faces differently. Rather, the data are consistent with the hypothesis that experience with ASL facial expressions can *fine-tune* certain face-processing skills. Nonetheless, these results do support the hypothesis that knowledge and use of a particular language (ASL) can influence nonlinguistic cognitive processes. Such an effect has implications for modular theories of mind (e.g., Fodor, 1983). Fodor has argued that linguistic processes are "encapsulated," insulated from other types of processes. Our results suggest that central aspects of ASL processing (perhaps mechanisms involved in recognizing and processing grammatical facial expressions) are not domain-specific (applying only to language) and are not insulated from other types of visual processing. Furthermore, Nachson (1995) and Farah (1996) (among others) have suggested that face processing itself is a modular system, similar to language. Again, our results provide some limits on the nature of this modularity. Since human face processing ability can be manipulated by certain types of experience, it suggests that these mechanisms are somewhat plastic (even in adulthood) and may be recruited for other processes, such as interpreting linguistic information expressed by the face.

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