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*Neuropsychological Studies of Linguistic and Affective Facial Expressions in Deaf Signers**

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KEY WORDS

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aphasia

asymmetry

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facial expression

ABSTRACT

For deaf users of American Sign Language (ASL), facial behaviors function in two distinct ways: to convey affect (as with spoken languages) and to mark certain specific *grammatical* structures (e.g., relative clauses), thus subserving distinctly linguistic functions in ways that are unique to signed languages. The existence of two functionally different classes of facial behaviors raises questions concerning neural control of language and nonlanguage functions. Examining patterns of neural mediation for differential functions of facial expressions, linguistic versus affective, provides a unique perspective on the determinants of hemispheric specialization. This paper presents two studies which explore facial expression production in deaf signers.[1] An experimental paradigm uses chimeric stimuli of ASL linguistic and affective facial expressions (photographs of right vs. left composites of posed expressions) to explore patterns of productive asymmetries in brain-intact signers. A second study examines facial expression production in left and right brain lesioned deaf signers, specifying unique patterns of spared and impaired functions. Both studies show striking differences between affective and linguistic facial expressions. The data indicate that for deaf signing individuals, affective expressions appear to be primarily mediated by the right-hemisphere. In contrast, these studies provide evidence that *linguistic* facial expressions involve left hemisphere mediation. This represents

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an important finding, since one and the same muscular system is involved in two functionally distinct types of facial expressions. For hearing persons, the right-hemisphere may be predominant in affective facial expression, but for deaf signers, hemispheric specialization for facial signals is influenced by the purposes those signals serve. Taken together, the data provide important new insights into the determinants of the specialization of the cerebral hemispheres in humans.

HEMISPHERIC SPECIALIZATION FOR AMERICAN SIGN LANGUAGE

The study of brain damaged individuals with different sensory and language experience offers a revealing vantage point from which to examine the organization of higher cognitive functions in the brain, as well as the degree to which that organization may be modified. American Sign Language (ASL) displays the complex linguistic structure found in spoken languages, but differs in surface form from spoken languages in a number of highly significant ways. Key signal properties of American Sign Language rely upon visual-spatial manipulations of the hands in relation to the body, and linguistic structure is conveyed through the manipulation of these spatial relationships. ASL thus exhibits properties for which each of the hemispheres of hearing people shows a different predominant specialization. Despite the modality differences, studies with right- and left-hemisphere damaged deaf signers have demonstrated the importance of the left hemisphere in mediation of sign language, particularly sign language production (Poizner, Klima, & Bellugi, 1987; see Corina, 1998a, 1998b for recent reviews). It has been found, for example, that in congenitally deaf signers, damage to the left cerebral hemisphere, but not to the right, leads to frank sign language aphasias. Furthermore, the breakdown of sign language is not uniform, but rather cleaves along linguistically relevant lines. The fact that the components of sign language (e.g., lexicon and grammar) can be selectively impaired is important for the investigation of the neural correlates of language. Equally important are studies showing that damage to the right cerebral hemisphere of deaf signers, but not to the left, leads to gross impairment in nonlanguage spatial functioning, yet leaves sign language production essentially intact. Recent functional imaging studies have also reported robust left-hemisphere participation during linguistic processing tasks (Neville et al., 1998). However, fMRI studies have suggested a greater role of the right-hemisphere in ASL comprehension than would be predicted by the aphasia studies alone. These findings have led some to speculate that the hemispheric demands for ASL production and comprehension may differ in significant ways, with sign production being largely left lateralized and comprehension requiring bilateral mediation (Corina, Bavelier, & Neville, in 1999; see Peperkamp & Mehler, this issue, for a survey of the literature on sign language and the brain).

Although studies of brain organization for sign language have focused largely on core aspects of language in the hands (phonology, morphology, and syntax), recent investigations have begun to widen the scope of inquiry to include discourse level phenomena (Lowe, Kegl, & Poizner, 1997). In addition, there is growing interest in another layer of structure in the language—facial expressions (Kegl & Poizner, 1997; Lowe, Kegl, & Poizner, 1997). ASL has evolved grammatical patterning with a distinct preference for conveying information in simultaneous channels. In ASL, a variety of specific facial signals have arisen as part of the grammaticized apparatus, co-occurring with manual signals. In this paper we focus on the underlying neurological control of facial expression in production: the use of facial muscles for two distinct purposes—linguistic versus affective. The first experiment involves judgments of chimeric stimuli of ASL signers (photographs of right vs. left composites of linguistic vs. affective expressions). A second study examines facial expression (linguistic vs. affective) in left and right brain lesioned deaf signers, specifying unique patterns of spared and impaired functions. These studies provide important new insights into the determinants of functional specialization of the cerebral hemispheres in humans.

The contrast between linguistic and nonlinguistic facial expressions in ASL.

The use of facial expressions in the service of communication has a clear evolutionary basis. In many species facial displays serve multiple functions: alerting, threatening, greeting, displaying affiliation, playing, and so forth. Humans are no exceptions; facial expressions serve a host of functions and provide a way not only to predict behavior, but also to display and manipulate behavior (Cole, 1998). The most common domain of study in human facial expression concerns emotional facial expressions. However, the question of what constitutes human emotion is itself conceptually ambiguous (Ekman, Friesen, & Ellsworth, 1982), and for this reason, any attempt to classify specific facial expressions as emotional or nonemotional is likely to bring forth criticism. The present paper makes a strong distinction between "affective" facial expression (used to convey emotion), and a class of linguistic facial expressions used in American Sign Language. While it will be easy to objectify specific linguistic facial expressions, the present paper does not attempt to fully differentiate the shades of gray which constitute the class of nonlinguistic affective facial expressions. However, for the purpose of this study, "affective" expressions refer to those expressions which convey a speaker's true-felt emotion and those expressions used in the service of communication to convey the emotional tenor of a past event. The latter may be considered by some to fall within the pragmatic level of communicative structure.

A growing body of literature indicates that, for users of American Sign Language (ASL), facial expressions serve two distinct functions; they convey affective or pragmatic message level information, and, as a requisite part of the grammar of ASL. Some of the earliest reports of linguistic function of facial expression in ASL were observed in studies of syntactic structures such as relative clauses and conditionals (Liddell, 1977; 1980). A particularly comprehensive analysis of ASL nonmanual question behavior was reported by Baker-Shenk (1983). More recent studies have described the role of facial expressions in signaling, clause structure (Petronio, 1993), foregrounding (Wilbur, 1994), agreement (Bahan, 1996), and tense (Aarons, Bahan, Kegl, & Neidle, 1995). For general and accessible, though early, overviews readers are directed to Baker and Padden (1978), and Baker and Cokely (1980). Studies of the development of facial expression in deaf signers can be found in Reilly, McIntire and Bellugi (1990a,b). A preliminary study of some linguistic facial expressions in Israeli Sign Language is reported in Nespor and Sandler (this issue).

The normal production of affective facial expression varies in intensity, waxing and waning throughout the utterance, and transitions do not correspond to clear linguistic unit boundaries. In contrast, grammaticized facial expressions in ASL fall into at least two distinct classes. One class of facial expressions signals a variety of *syntactic structures* (conditionals and relative clauses, for example), which are obligatorily marked by specific facial expressions. A second class of facial expressions signals *adverbial markings*; these expressions co-occur with and modify verb phrases. Unlike affective facial expressions, these classes of linguistic facial expressions make use of individuated facial muscles, are specific in scope and timing, are coordinated with the sentences and other constituents of ASL, can serve specific linguistic functions, and are required by the grammar of the language.

Syntactic facial markers. Specific facial expressions are required to mark complex syntactic constructions in ASL such as conditionals, relative and other embedded clauses, topics, and questions. Compare the pairs of examples (1) and (2) (after Liddell, 1980):

(1) Facial Signals: rel. cl.
ASL: DOG CHASE CAT, COME HOME
English Translation: 'The dog that chased the cat, came home.'

(2) ASL: DOG CHASE CAT, COME HOME
English Translation: 'The dog chased the cat and then came home.'

The first sentence involves a relative clause, signaling the particular dog that chased the cat. The nonmanual facial signal for a relative clause involves a brow raise, an asymmetric cheek and upper lip raise, and a backwards tilt of the head. The second utterance represents two conjoined propositions, *the dog chased the cat and then the dog came home.* The meaning of the two sentences is different, although the sign strings are the same. Specific facial expressions also obligatorily mark conditional clauses in ASL, as in sentences (3) and (4):

(3) Facial Signals: cond.
ASL: TODAY RAIN, PICNIC CANCEL
English Translation: 'If it's raining today, the picnic is canceled.'

(4) ASL: TODAY RAIN, PICNIC CANCEL
English Translation: 'It's raining today, and the picnic is canceled.'

The constellation of nonmanual behaviors required to mark conditional sentences includes a brow raise, a slight head raise and tilt, a shift of eye gaze, and an eye blink. Note that with the nonmanual component, the sentence is interpreted as a conditional; without it, the same manual string is interpreted as two simple conjoined propositions. It is the presence and scope of the facial markers that make examples (1) and (3) complex sentences with subordinate clauses.

Adverbial facial markers. A second set of facial signals marks the equivalent of adverbial modifiers on verb phrases in ASL. Compare the following two sentences:

(5) Facial Signals: /mm/
ASL: HER HUSBAND COOK[durational] DINNER
English Translation: 'Her husband has been cooking the dinner with pleasure.'

(6) Facial Signals: /th/
ASL: HER HUSBAND COOK[durational] DINNER
English Translation: 'Her husband has been cooking the dinner inattentively.'

Sentences (5) and (6) involve the same signs, but with different adverbial facial expressions occurring over the modulated verb phrase. One facial expression (/mm/)

involves protrusion of the lips, and the other involves a slight tongue protrusion (/th/). If the uses of these two different facial expressions were operating in the same way, we would expect similar interpretations of these two sentences, but very different interpretations are given. In (5) the cooking is done with pleasure, normally, while in (6) the cooking is done automatically, without awareness, without thinking about it. In ASL, predicates inflected for specific grammatical aspect like DRIVE[Continuative] or COOK[Durational] require a co-occurring facial adverb.

In contrast to the grammatical facial signals in examples (1), (3), (5), and (6) which have highly distinctive properties, are affective facial signals which also co-occur with ASL and spoken English. Example (7) expresses the speaker's surprise, as in, "I am surprised that her husband is cooking dinner," whereas examples (5) and (6) specify the manner in which her husband is cooking dinner, with pleasure or relaxed enjoyment in one sentence, and thoughtlessly or inattentively in the other. These sentences highlight one of the differences between nonlinguistic facial expressions and linguistic facial expressions. In the former, the expression (i.e., "surprise") operates on a pragmatic level, whereas in the latter the facial expressions (i.e., /mm/ or /th/) function as part of the grammatical structure of the sentence (in these cases as adverbials modifying the verb phrase).

(7)

((surprise))

Facial Signals:

ASL Glosses: HER HUSBAND COOK DINNER

English Translation: *"Her husband is cooking dinner."*

The shape of the line is an approximation of the musclar intensity observed for emotional expressions.

Distinguishing between Linguistic and Affective Faces

Linguistic and affective markers differ in ASL in distinctly measurable and quantifiable ways, as research by Baker and Padden (1978), Baker-Shenk (1983), Liddell (1977, 1980), and Reilly, McIntire, and Bellugi (1991) has shown. In addition to functional differences, there are at least four essential distinctions between affective and linguistic facial expressions in ASL that mark the differential use of the same facial musculature:

(a) *Rapid onset and offset of muscle firing.* Affective facial expressions are inconsistent and inconstant in their onset and offset patterns and in their apex shape (e.g., Example 7). In contrast, linguistic facial expressions in ASL, such as those exemplified in (3), (5), and (6) above, have a very clear, rapid, and specific onset/offset pattern.

(b) *Individuated facial muscles.* Affective and linguistic facial expressions differ significantly in the use of conglomerate versus individuated facial muscles. Affective facial actions are global and make use of integrated conglomerate sets of facial muscles. In contrast, grammatical facial expressions in ASL may single out individual facial muscles that are never individuated in the normal expression of emotion. Ekman (pers. comm.) has noted that the grammatical facial behaviors that are part of the linguistic system of ASL are markedly different from the use of facial muscles displayed in emotional state. He specified that the rapid onset and rapid offset of firing of individual facial muscles is unique to this linguistic system, and that the individual facial muscles (e.g., in relative clause marking) are rarely, if ever, isolated in affective displays.

(c) *Linguistic Scope.* A critical difference between affective and linguistic facial expressions lies in the scope of the facial expressions. For affective facial expressions accompanying sign (or speech), there are many possible patterns of execution. Affective expressions may occur well before or well after a linguistic utterance and are not necessarily time-locked to specific linguistic events. In contrast, grammatical facial expressions are crucially coordinated with manual signs. The scope of linguistic facial expressions demarcates discrete grammatical boundaries.

(d) *Requiredness.* As Reilly, McIntire, and Bellugi (1990a) point out, the linguistic facial marker for the functional equivalent of a relative clause or conditional is required in ASL, whereas the associated manual markers (e.g., the word IF in the case of the conditionals) are optional. Moreover, as we have shown above, there are also required contexts for adverbial linguistic markers.

In sum, linguistic facial behaviors in ASL constitute a limited set of discrete/categorical behaviors in which constituents, scope timing, and shape are rule-governed and dictated by the requirements of the linguistic system. In contrast, affective facial behaviors are continuous, displaying wide variation along all these parameters.

Background studies of facial expression in ASL

The emergence of facial expression in deaf children. By the end of their first year, all infants (deaf and hearing alike) consistently use basic, universal affective facial expressions, both to express and to interpret emotional states (Campos, et al., 1983). In considering the acquisition of linguistic facial expression, deaf babies learning ASL confront an unusual developmental task. Like hearing infants, they become fluent users of affective facial expression by their first birthday. However, as language emerges, deaf infants must learn to use faces linguistically as well. One obvious route to the acquisition of grammatical facial signals would be for the child to extend and generalize prelinguistic affective communicative abilities into appropriate linguistic contexts. This would imply one global system of facial expression that serves both linguistic and affective functions. Alternatively, she might ignore the similarities in the signals and treat the grammatical facial signals as a separate system, that is, as linguistic information, to be independently analyzed. Studies of deaf children (Reilly & Bellugi, 1996; Reilly, McIntire, & Bellugi, 1990a,b, 1991) indicate that facial expression is not treated as a single unified system; affective expression does not simply generalize to language. Rather, grammatical facial expression is acquired as part of the linguistic system, in a gradual, analytic, and rule-governed manner. For example, the required nonmanual signal for *wh*-questions includes furrowed brows (Baker & Cokely, 1980; Baker-Schenk, 1983), and toddlers fluently use this same facial expression to express anger and puzzlement. However, when deaf children begin to produce *wh*-questions (at ca. 18 months of age), they use the manual *wh*-signs, for example, WHAT, WHERE, with blank faces. It is not until age three-and-a-half to four that we see children accompanying their *wh*-questions with the required nonmanual behaviors. Thus, grammatical facial behaviors appear to be acquired much like other types of bound morphology. These data on *wh*-questions and comparable patterns in the acquisition of conditional sentences and their required nonmanual behaviors suggest a bifurcation of systems in which facial expression is differentially mediated by affect and language in the developing deaf signing child.

Facial discrimination in signers. There is evidence that experience with sign language improves the ability to discriminate facial information. Bettger, Emmorey, McCullough and Bellugi (1997) report that native deaf and native hearing signers performed significantly better than hearing nonsigners in a task of facial discrimination. Interestingly, deaf signers who acquired sign language early in childhood also showed enhancements in facial discrimination. These authors speculate that the increased reliance on facial expression in the service of linguistic contrasts may give rise to an overall enhancement in the discrimination of facial information.

Recognition of facial expression in ASL. Corina (1989) examined recognition of facial expression in deaf signers. In a comparison of processing of affective and linguistic facial expression, Corina used a lateralized recognition accuracy test for facial expressions. The linguistic expressions represented unfamiliar facial expressions for the hearing subjects, whereas they served as meaningful linguistic symbols for deaf signers. Hearing subjects showed consistent and robust left-visual field advantages for both types of facial expressions. In contrast, deaf subjects showed inconsistent and reduced patterns of hemispheric asymmetry in response to linguistic and affective facial expression stimuli. Vargha-Khadem (1983) reported a right-visual field superiority for face identification in deaf children, a pattern opposite that found for hearing children. These studies suggest that for hearing nonsigners, the right-hemisphere may predominate in the recognition of all forms of facial expression. For deaf signers, hemispheric specialization for the processing of facial signals, and may be influenced by the functions these signals serve.

The underlying motoric and neural substrate of facial expression

An important issue not addressed in previous studies is the underlying motoric and neural substrate of facial expression production in deaf signers. Much is known about the physiological mechanisms underlying facial expression production (Rinn, 1984). Distinct neural pathways subserve voluntary and involuntary production of facial expressions. Involuntary facial movement or “felt” emotion are considered to be subserved by the largely subcortical and phylogenetically older extra-pyramidal motor systems. In contrast, voluntary or “posed” facial expressions are considered to emanate from the cortical motor strip and course the facial nuclei via the pyramidal tract. Importantly, fibers of the pyramidal system innervating the lower half of the face emanate exclusively from the contralateral hemisphere. This stands in contrast to the innervation of the upper facial musculature, which tends to be bilateral. Given the existence of contralateral control of the lower facial musculature, it is not surprising that asymmetries are found in the execution of voluntary facial expressions, as motor systems in general tend to show behavioral asymmetries, (e.g., handedness, eyedness, footedness).

The role of the right-hemisphere in affective facial expression. Studies of affective facial expression have observed reliable asymmetries of the facial musculature. Greater left-sided rather than right-sided expressive intensities in right handed persons have been widely reported. Several methods have been devised for quantifying these asymmetries: subjective ratings of facial expressions, measurements of muscle displacement, and use of composite photographs. These methods have yielded similar findings (Borod & Caron, 1980; Campbell, 1978; Ekman, Hager, & Friesen, 1981; Sackheim, Gur, & Saucy, 1978). Recent reviews and meta-analysis confirm the presence of right-sided asymmetry in emotional facial expressions (Borod, 1993; Borod, Haywood, & Koff, 1997; Skinner & Mullen, 1991; but see also Gazzaniga & Smylie, 1990). Moreover, recent work suggests this expressivity of "facedness" may not be species-specific. Hauser (1993) has reported that in the rhesus monkey, the left side of the face is dominant in emotional expression. Researchers have attributed this facedness asymmetry to the greater role of the right-hemisphere in the mediation of affective behaviors (Borod & Caron, 1980; Borod, Haywood, & Koff, 1997; Campbell, 1978; Moscovitch & Olds, 1982). Additional evidence for the role of the right-hemisphere in the production of facial expressions comes from comparisons of facial expressivity in left- and right-hemisphere damaged persons. These studies suggest intact spontaneous facial gesturing in left-hemisphere damaged subjects, and lack of, or reductions in, facial expressivity following right-hemisphere damage (Borod & Koff, 1990; Borod, Koff, Perlman, Lorch, & Nichols, 1985; Feyereisen, 1986; Ross & Mesulam, 1979).

Mouth asymmetries during speech. In contrast to the left-sided asymmetries for affective expression, studies of mouth asymmerty during speech behaviors have indicated greater right-sided lip opening, especially during propositional speech (Graves, Goodglass & Landis, 1982; Graves, Landis, & Simpson, 1985; but see also Hager & Van Gelder, 1985). These data have been taken as evidence for a greater role of the left-hemisphere in the articulation of propositional speech. The relative importance of the left half of the face during the interpretation of lip-read sounds is consistent with these production findings (Burt & Perrett, 1997). Taken together, these findings suggest that productive facial asymmetries may, in part, reflect distinct underlying patterns of cerebral dominance for affect and language.

Below we present findings from two experiments of facial expression production in signers of ASL. The first experiment involves judgments of chimeric facial expression stimuli provided by ASL signers. A second study examines linguistic and affective facial expression production in left- and right-lesioned deaf signers, specifying unique patterns of spared and impaired functions. These studies provide important additional insights into the determinants of the specialization of cerebral hemispheres for facial expression mediation.

EXPERIMENT I

Judgment of chimeric facial stimuli: linguistic versus affective expressions

Experimental literature reports asymmetric productions of voluntary and involuntary affective facial expressions in adults and children and indicates greater left-sided intensity of expression. This is taken as evidence for the greater role of the right-hemisphere in the production of these expressions. The question arises: do deaf signers show similar expressive asymmetries across both affective and linguistic facial expressions? In this study, we examine expressive asymmetries in signers of American Sign Language. Hearing raters unfamiliar with sign language judged relative intensity of composite photographs of sign language users exhibiting affective and linguistic facial expressions. All three ASL models were highly skilled signers with life-long experience in signing and strongly right handed. One was a hearing interpreter for the deaf who had been signing for 20 years, and interacted daily with members of the deaf community both personally and professionally. The other two were congenitally deaf females, whose primary and preferred language was American Sign Language. Both deaf subjects attended residential schools for the deaf and grew up in signing households.

Each of the three ASL models was asked to pose both linguistic and affective facial expressions: three affective expressions (e.g., happy, sad, angry) and three linguistic expressions (e.g., /mm/, /th/, /pursed/). The three linguistic expressions were chosen because they tend to be associated with lower mouth articulation: /th/ involves the partial protrusion of the tongue through the extended and up rounded lips; /mm/ involves the flattened protrusion of the lips; and /pursed/ involves the tightening of the lips with a slight opening. The facial expressions /th/ and /mm/ are facial adverbs, /th/ signifies “inattentiveness” or “without awareness,” and /mm/ signifies “relaxed enjoyment” or “with pleasure.” The /pursed/ expression typically signifies “sparseness” or “thinness.”

Chimeric facial stimuli. Each photograph was developed in correct and mirror-reversed orientation (accomplished by flipping and reprinting the negative). This resulted in two photographs for each facial expression. Each of these photos was then carefully bisected and recombined. One half was composed of the correct orientation, the other half derived from the mirror reversed half. This process resulted in two reconstructed photographs, one composed solely of left-left halves (L-L) and one composed solely of right-right halves (R-R). These composites were then mounted on a black background and rephotographed (see Figure 1). The resulting photographs provided natural looking chimeric faces with little evidence of the reconstruction that was used to derive the composites.

Each pair of the 36 resulting facial expression photographs (nine left-left affective, nine right-right affective, nine left-left linguistic, nine right-right linguistic) were then mounted vertically, framed, and bound in a notebook. Thus, on any one page, two photographs of the same expression were presented, one L-L and one R-R. The position of the pairs (top or bottom) was counterbalanced. Importantly, the frames were cut individually for each photograph, and allowed exposure of only the lower half of the face (the face below the lower eyelid). The use of only the lower half of the expression is motivated by anatomical considerations outlined in the discussion above: only the lower half of the face is contralaterally innervated. Thus the judgments of expressivity were limited to this anatomical region. It is important to emphasize that the goal of the study is to examine asymmetries in the form of the expressions and is not an assessment of their intended valence (affective or otherwise).

Method. The photographs were ordered randomly for blocked free viewing presentation with the constraint that no more than two successive pages were of the same model. Thus, subjects saw first either nine pairs of linguistic expressions or nine pairs of affective expressions. Two sets of instructions were used. One group of subjects received the “Expressive” instructions, in which they were asked to leaf through the note book and for each pair of photographs, pick the expression that was most “Expressive.” Expressiveness

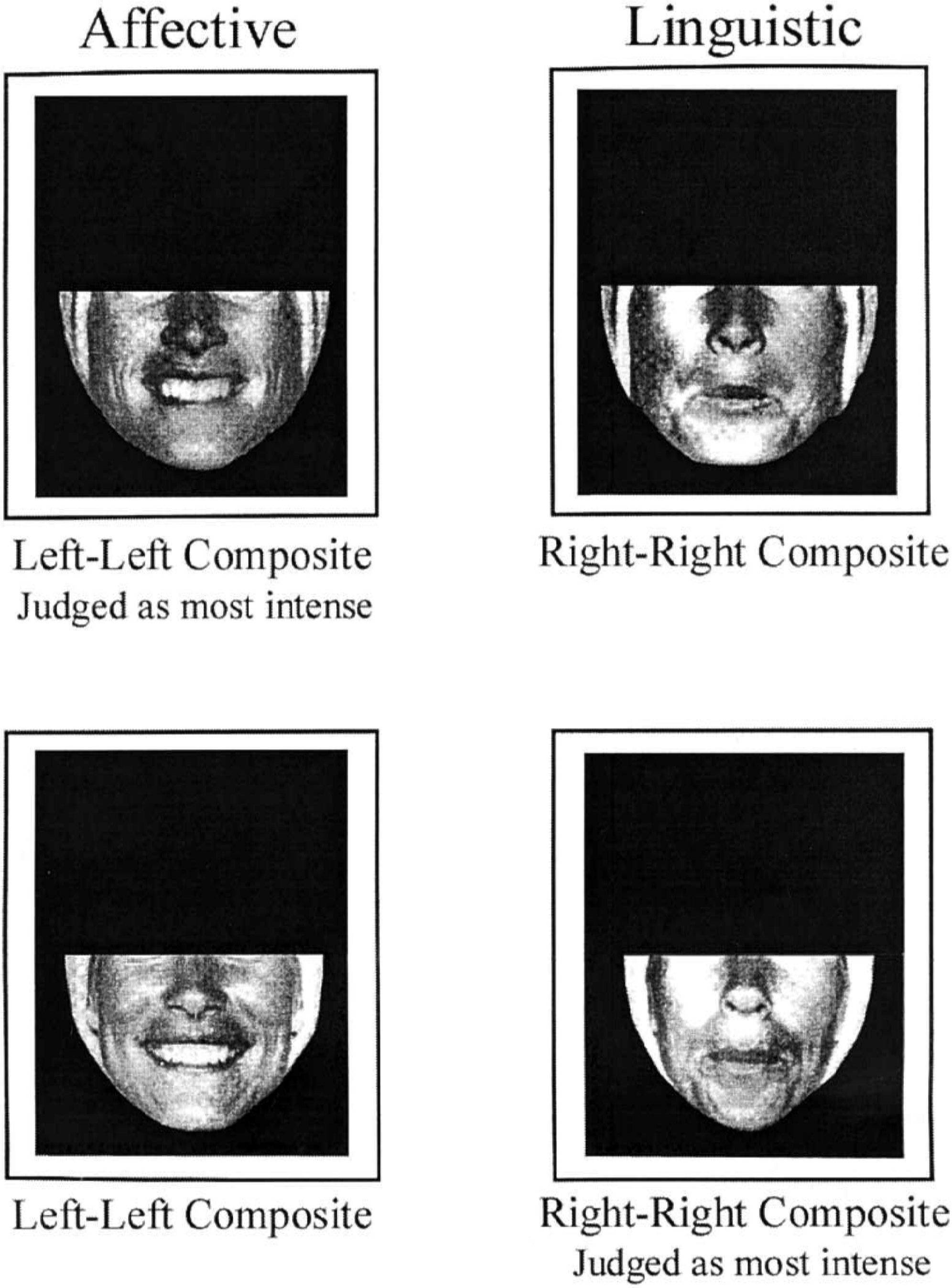

Figure 1

Chimeric Facial Expressions.

TABLE 1

Judgments of linguistic and affective chimerics

	Expressive Judgments (n=30)		***Intensity Judgments (n=38)***	
	Right-half	*Left-half*	*Right-half*	*Left-half*
Affect Expressions	126	144	171	171
	n.s.		n.s.	
Linguistic expressions	162	108	254	88
	$^*p<.05$		$^*p<.01$	

was defined as follows: “The most expressive picture is the one that most typically represents the canonical expression.” For example, the most “surprised” of a surprised expression would be the one to pick. The second group of subjects was instructed to pick the photograph that was the most “Intense.” Intensity was defined as follows: “The facial expression which most strongly influences the musculature; that is, produces the most wrinkles or stretches the skin most intensely.” In essence, the two instructional conditions were designed to focus one group of subjects on the affective component of the facial expression (the “expressive” condition) and the other group of subjects on the rating of intensity of facial asymmetry devoid of emotional content (the “intense condition”).

Subjects and procedure. A total of 68 hearing undergraduate students with no knowledge of American Sign Language served as raters. Subjects were told that they would recognize some of the facial expressions, while others may be novel. Thirty hearing subjects received the “Expressive” instructions, while 38 hearing subjects received the “Intense” instructions. Half of each group judged the affective expressions first and the linguistic expressions second; and the other half of each group received the reverse ordering. Subjects compared each expression pair for roughly 10 s, and then pointed to the expression they felt was most “expressive” or most “intense.” Subjects’ responses were entered into a coding sheet.

Results. To examine whether facial expressions were judged asymmetric by the viewers, we tallied the number of right-half and left-half composite choices per condition. A chi-squared test was used to determine if the distribution of responses was different from chance. The results are shown in Table 1.

As is clear from Table 1, judgments of the linguistic expressions yielded a nonrandom distribution indicating greater expressiveness and intensity for linguistic right-half composites (Expressive $\chi^2 = 5.2$, $df = 1$, $p < .05$; Intense $\chi^2 = 31.59$, $df = 1$, $p < .01$). In contrast, neither the expressivity nor intensity judgments yielded statistically significant differences for the affective facial expressions. However, there was a slight trend for left-half affective composites to be judged more “expressive.” Overall, subjects receiving the Intense condition were statistically more reliable than those receiving the Expressive condition. This result may reflect the difficulty that these untrained subjects had in making expressivity judgments for the unfamiliar linguistic expressions.

An unexpected finding was the lack of strong asymmetry for affective facial expression judgments. Methodological factors may have contributed to this result. There is some suggestion that subjects found making intensity judgments for the linguistic expressions easier than making those same judgments for the affective expressions. This discrepancy may have reduced the subjects' sensitivity for the detection of the subtle asymmetries present in the affective conditions. This hypothesis receives support from the presence of a condition order effect, that is, whether subjects received the affective expression condition before or after the linguistic expression condition influenced the statistical reliability of the effect. Specifically, for those subjects making intensity judgments of the affective expressions prior to making intensity judgments of the linguistic expressions we observe a significant left bias for affective expressions ($\chi^2 = 4.96$, $p < .05$) compared to subjects who received the linguistic expressions prior to the affective expression. This order effect may be evidence that making decisions to the linguistic expressions influenced later judgments of asymmetry for the affective expressions. In addition the use of only the lower half of the face may have contributed to the null effects for affective expressions. For example, expression such as anger are largely conveyed via eyebrow information, information which is not present in these stimuli (see Borod & Koff, 1990; Skinner & Mullen, 1991 for discussions of methodological issues in cheremic expression research).

Discussion

Overall it is clear that subjects viewed the linguistic expressions as being highly asymmetrical, and in fact in a direction that is opposite from what is traditionally found for affective expressions. That is, subjects in each instruction condition viewed the Right-Right linguistic composites as being more "expressive" or more "intense." In contrast, the results for the affective condition were weaker; however, a trend for the expressive condition was in the direction previously reported in the literature. Subjects tended to choose the Left-Left affective halves as being more expressive; however, this trend only reached significance for affective facial expressions observed in one condition order for "intensity" judgments. Taken together, these findings suggest that hemispheric specialization for linguistic facial expression production in the deaf may be mediated by the left-hemisphere. This finding would support the hypothesis that laterality differences underlying facial asymmetries arise from the functional content of the expression and are not simply a reflection of the peculiarities of the motor system underlying facial expression. This left-sided intensity of linguistic facial expression in ASL extends the findings of greater left-sided mouth opening during speech behaviors (Graves, Goodglass, & Landis, 1982) in an important and profound way. One can argue that the mouth asymmetries observed during speech are simply a by-product of the lateralization of language. The end product of speech is not a particular facial grimace, but a well-coordinated set of articulatory commands that results in a specific acoustic target. However, in ASL the end product of the linguistic command is a facial expression. Thus, the data from ASL provide strong evidence that the neural mediation of facial expression itself may be functionally specified.

The lack of robust asymmetry for affective facial expression judgments was unexpected. This may be a reflection of the fact that hemispheric control of affective expressions in fluent signers is more bilateral than that observed in hearing individuals. However, as discussed, methodological factors may have contributed to the lack of statistically significant asymmetry for affective expressions.

The differential face asymmetries observed in the chimeric photograph experiment suggest differential control of linguistic and affective facial expression in fluent users of ASL. A different line of evidence comes from investigating the effects of right versus left-hemisphere lesions on the production of facial expressions in ASL. Since one and the same set of facial muscles is used in linguistic and affective facial expressions in ASL, evidence from disruption of these two classes of facial signals following brain damage can be very revealing. To examine this issue, we quantified spontaneous facial expression behaviors in two deaf signers, one with a right-hemisphere lesion and one with a left-hemisphere lesion.

EXPERIMENT 2

Specialization for linguistic versus affective facial expression in brain damaged deaf signers

In ASL communication there is an abundance of affective and linguistic facial markers. ASL narratives provide a rich context for the exploration of the neural substrates of linguistic and affective organization. Here we examine the effects of right and left lesions on deaf signers, focusing on their use of the two contrasting modes of facial expression: linguistic versus affective. We examine two cases with comparably large lesions involving both cortical and subcortical areas, one with left-hemisphere damage and the other with right-hemisphere damage. We present a summary of the patients' lesions, their sign language profiles (as measured by the The Salk Sign Diagnostic Aphasia Battery), and their performances on nonlanguage visuospatial tasks. Both subjects were right-handed before their strokes, and both were members of the Deaf community and life-long signers. We examine their production of facial expressions, contrasting affective expressions with linguistic expressions.

Neurological characteristics of right- and left- lesioned signers

Sarah M. is a congenitally deaf signer who suffered a right-hemisphere stroke one year prior to testing, at the age of 70. After her right-hemisphere stroke, her signing remained clear and unaffected. However, the stroke had a profound effect on her nonlanguage visuospatial capacities. A neurological examination of Sarah M. revealed a paralysis of the left arm and leg, and moderate increased reflexes in the entire left side. A CT scan at the time of testing shows a very large lesion occupying most of the territory of the middle cerebral artery. The lesion extends from the frontal operculum (the right-hemisphere homolog of Broca's area), and involves premotor, motor, and somatosensory areas, including the inferior parietal lobule (supramarginal gyrus and part of the angular gyrus). The lesion involves not only these cortical areas, but the underlying subcortical areas (Figure 2). Her family noted that her personality was different following her stroke, and the investigator noted a general flattening of affect. These remarks prompted a closer investigation of Sarah M.'s facial expression after her stroke.

Gail D. is a congenitally deaf signer with a left-hemisphere lesion. Her case resulted in a Broca-like signing profile, the first case of agrammatism for sign language to be reported in the literature. Although initially Gail D.'s entire right side was affected, she had

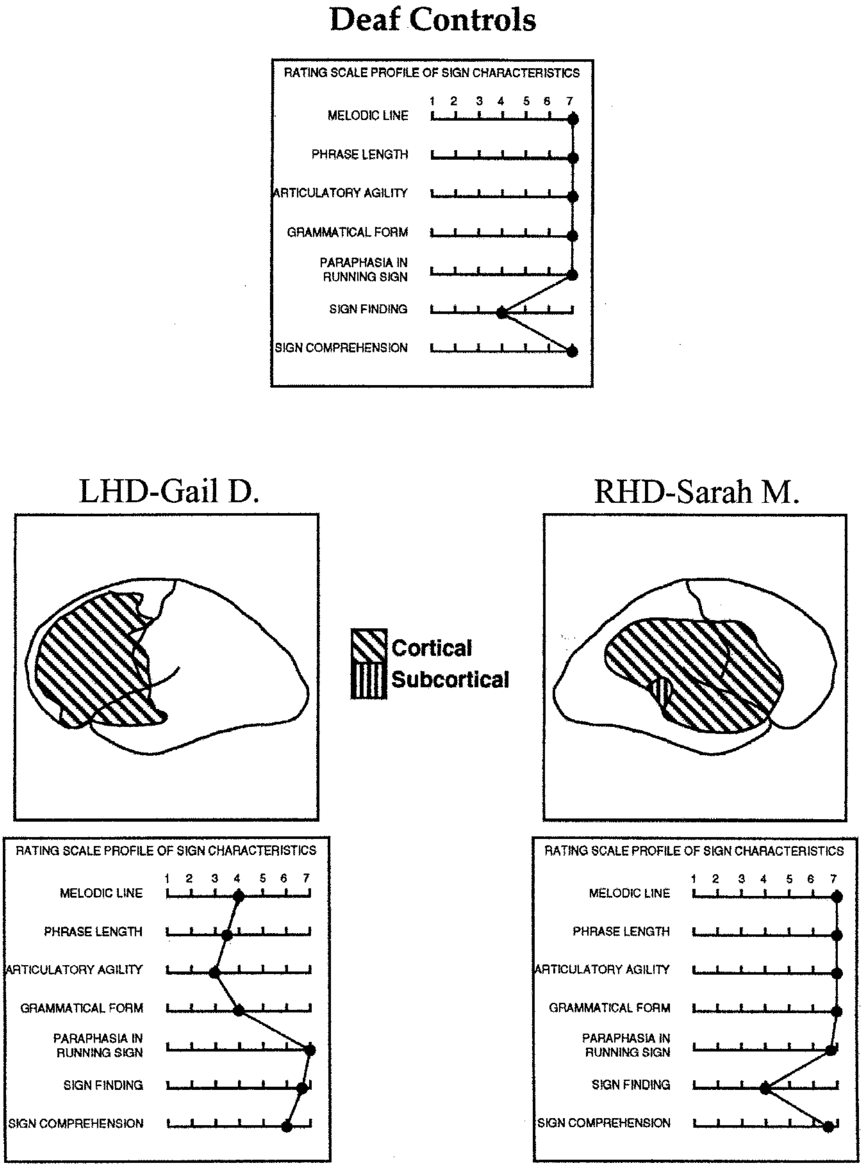

Figure 2

Lesions and Salk Sign Aphasia Profile for Gail D. and Sarah M.

regained the use of her leg and face; her right arm, however, remained paralyzed. She had no apparent sensory deficit. A CT scan performed eleven months after her stroke showed a left-hemisphere lesion that involved most of the convexity of the frontal lobe, including Broca's area and the anterior portions of the superior and middle temporal gyri (Figure 2). At the initial time of testing, one year after her stroke, Gail D.'s signing was clearly agrammatic (reported in Poizner, Bellugi, & Klima, 1989. More than a year after our initial visit with Gail D., we tested her again using a range of ASL tests and the Salk Sign Diagnostic Aphasia Battery. By this time there had been substantial progress in her communicative abilities. Gail D. was no longer limited to single sign utterances; her mean phrase length had improved from one to 3.5 signs. Gail D. still had some lingering agrammatic tendencies, (e.g., incorrect use of or lack of verb agreement, and some word finding difficulties). However, her sentences were longer and she now used a greater range of grammatical forms. This improvement allowed us to examine the provision of accompanying linguistic and affective facial expressions.

Method. A narrative and a free conversation passage from Sarah M. and from Gail D. were videotaped and transcribed by two deaf native-signer researchers. Each viewed the videotapes independently, making note of all facial behaviors (including affective and linguistic expressions), and excluding from consideration any instances where the image of the signer's face was not clear on the videotape. The two raters had high agreement for facial expressions observed in Sarah M. (inter-rater reliability .89) whereas coding of facial expression in subject Gail D. were less reliable (inter-rater reliability .62). Due to this discrepancy we chose to limit our comparisons to those instances of expressions which were common to both raters. This resulted in 41 utterances for S. M. and 39 for G. D.

Three techniques were used to quantify the data. First, we derived an index of productive expressivity which provides a measure of the relative frequency of expression type (affective or linguistic) for each subject. The ratio obtained expresses the number of affective expressions relative to the number of linguistic expressions. Thus, a subject who showed equivalent amounts of linguistic and affective facial expressions for a given passage would have an expressivity ratio of 1:1. Due to the unconstrained nature of the corpora, we could not predetermine how often affective and linguistic expression ought to occur. For this reason it is not appropriate to provide between subject statistical measures based on the absolute number of occurrence of expression type. Given the wide range of individual differences in facial expressivity in the normal population, it is likely that such comparisons would violate assumptions of homogeneity of variance required for statistical tests. Using a ratio measure in essence allows each subject to serve as their own control. However, as discussed below, both subjects deviate markedly from this idealized ratio.

Second, in order to provide an objective measure of the facial expressions we observed in these subjects, we used Ekman and Friesen's Facial Action Coding System (FACS) (1978). One author (Reilly) is a certified FACS expert, and she coded the expressions from the deaf lesioned subjects. FACS is a comprehensive and anatomically based objective system for transcribing and coding facial activity in which the contractions of more than 40 individual facial muscles can be distinguished. FACS uses 46 "action units" to transcribe the firing of each of these muscles of the face (see Appendix 1 for Notation for FACS and ASL Notation Conventions).

Third, and admittedly more speculative, we asked the two raters to identify utterances where they felt a facial expression was expected/required, but was nevertheless absent. It should be noted that this was considerably easier for the linguistic expressions as the required context for the expression was generally evident. The task was more difficult for the affective expressions where these constraints do not hold. Given the difficulty in objectifying the "absence of occurrence" for these data we chose to document several clear examples of utterances which were judged as instances of missing linguistic and affective facial expressions (see below), rather than present an "unexpressivity ratio."

Results: Right lesioned signer. The results for Sarah M. were quite striking. In general, after her stroke Sarah M. showed dampened facial expression overall, and had very clear impairments in the facial expression of affect. Her productive affective-linguistic ratio was 1:4, confirming our impression that affective facial expressions were greatly reduced relative to linguistic expressions. The finding of reduction of affective facial expression in a deaf signer following right-hemisphere damage mirrors the findings reported in studies of hearing speakers (Borod, Koff, Perlman, & Nichols, 1985; Feyereisen, 1986; Ross & Mesulam, 1979). In contexts where affective facial expression would be expected, it was absent more often than not. This is true for both negative and positive emotions, as well as for both felt affect and decontextualized instances where she is reporting past emotions or emotions of others. We document several of these instances below.

Shown in Example (1) is a case where Sarah M. describes her past emotional state (including crying, being depressed and upset) but shows no facial affect at all, despite the intensity of emotion described in her signing. This lack of expressed facial affect is highly uncharacteristic of normal ASL signing.

(1) RHD-Sarah M.
ASL: SOMETIMES[Habitual] DEPRESS[Intense], CRY. WHEN I U-P-S-E-T, FIRST STROKE, I CRIED.
English translation: 'Sometimes I got depressed and I cried. When I first had my stroke, I became very upset about it and cried.'

In example (2), Sarah M. is describing the "Cookie Theft" Picture from the Boston Diagnostic Aphasia Examination. She indicates, by the intensity of her signing, that the woman who has left the water running in the sink is *really* stupid, but she does so without using any affective facial expression; her face is blank as she signs. In normal ASL signing, one might expect to see affective facial expression in this context. Note, however, the linguistic facial adverbial marker `/th/` is clearly evident in her signed sentence.

(2) RHD-Sarah M.
ASL: WOMAN WASH WATER $\overline{\text{OVERFLOW}}^{\text{th}}$ STUPID SHE STUPID
English translation: 'The woman washes (the dishes), the water flows and she didn't notice it. That's stupid, she's really stupid.'

In example (3), the experimenter had suggested with a smile, jokingly, that perhaps the woman in the "Cookie Theft" picture was deaf, and therefore she did not hear the water overflowing in the sink. Sarah M. responded openly, apparently appreciating the in-joke between two deaf people, but with no expression whatever on her face. Again, the lack of facial expression in this context is striking.

(3) RHD-Sarah M.
ASL: UMM, MAYBE RIGHT YOU.
English translation: 'Oh, maybe you're right!'

In fact, the appropriate circumstances for marking affective facial expression in contexts where she was experiencing emotion and decontextualized contexts where she was talking about emotional experiences, both for positive and negative emotions, were abundantly present in Sarah M.'s signed conversation. There was, however, little evidence of any affective facial expressions. Experience tells us that a normal deaf person would have expressed congruent facial affect in these cases.

In contrast to the profile of missing affective facial expressions, Sarah M. was remarkably consistent in providing the full range of grammatical and adverbial linguistic facial markers required in ASL sentential contexts. She showed evidence of the correct facial expressions for questions, negations, embedded clauses, topic markers, as well as a wide range of facial adverbs.

Sarah M.'s description of the "Cookie Theft" picture provides several examples of highly complex *linguistic* facial expression markings (see Examples 2, 4, and 5). For instance, in (4), she combined two simple propositions, subordinating one with a linguistic facial expression, and included a required adverbial facial marker on the verb of the second proposition.

(4) RHD-Sarah M.
ASL:
adv. cl.
/aw/
WOMAN WASH[continuative], WATER
/th/
OVERFLOW[habitual]
English translation: 'While the woman was washing the dishes, the water from the sink overflowed (and she didn't notice it).'

As shown in (4), Sarah M.'s execution of the subordinate clause facial marker begins precisely with the onset of the manual string, terminates exactly at the end of the antecedent clause, and the two clauses are separated by an eye blink (as is required in ASL). In addition, Sarah M. uses the facial adverbial /th/ meaning "carelessly" or "unintentionally" with the sign OVERFLOW[Habitual], with precise scope marking the verb only. In (5) there is additional evidence of adverbial facial marking.

(5) RHD-Sarah M.
ASL:
/mm/
TRY T-O TAKE C-O-O-K-I-E-S WRONG
SLIP FROM STOOL
English translation: 'Trying to take the cookies, unexpectedly (he) slipped off the stool.'

Although Sarah M. shows reduction in the use of affective facial markers, she uses facial expression clearly and, significantly, in precisely those linguistic contexts where it is required. In addition to supplying appropriate linguistic facial expressions for syntactic functions (negation, topic, question, embedded clauses), Sarah M. also has instances of appropriate adverbial facial markings. These markings together make use of both the top and the bottom half of the face, and although attenuated, are clearly present and recognizable in her ASL sentences. Sarah M. produced linguistic facial expressions in contexts where the grammar of ASL required them, and the scope and timing of these expressions was normal. The provision of linguistic facial markers where required contrasts markedly with her noticeable lack of emotional facial expressions where they would have been expected.

Results: Left lesioned signer Gail D.'s affective-linguistic ratio was 6:1 indicating an abundance of affective expression relative to linguistic expressions. Unlike Sarah M., left-lesioned signer Gail D. was clearly aphasic for sign language. We have seen her several times, and have charted the course of her recovery from a severe agrammatic aphasia. The evaluation of her facial expression during signing is based on our testing her more than two years after her stroke. By this time she was conversing relatively fluently and showed considerable recovery, although she was still aphasic, and produced many paraphasias (not considered here). She was using complex sentences, which included some subordinate clauses, and a wide range of grammatical forms. There were many linguistic contexts in which grammatical facial expression would be required in ASL as well as contexts in which affective facial expression would be expected. We note that she produced a wealth of affective facial expressions in her signing.

In Example (6), Gail D. is reporting her version of a conversation she had with her doctor while she was in the hospital after her stroke. The doctor implored her to keep the IV-tube in her arm, but according to her report, she firmly refused and told him to take it out. This is expressed with abundant affective facial expression and she comfortably shifts between reporting her emotions and those of her doctor.

(6) LHD-Gail D.
((imploringly))
ASL: DOCTOR, PLEASE KEEP IT IN!
((insistent-anger))
ME "TAKE IT OUT!"

English translation: 'The doctor implored me to please keep in (the intravenous feeding tube), but I insisted he take it out.'

In Example (7), Gail D. was describing the effects of a very severe hurricane that blew through her town and did a great deal of damage. In her signing, she fully expressed the severity of the storm and the swaying of the trees, with affective facial expressions accompanying her signs.

(7) LHD-Gail D.
((intense)) ((intense))
ASL: TOWN DAMAGED TREE[pleural] SWAY!
((shocked))
#B-A-D WIND!

English translation: 'The town was damaged. The trees were swaying; there were fierce winds.'

In contrast to her wealth of affective facial expressions, Gail D. produced very few linguistic facial expressions; for the most part she failed to produce linguistic expressions where they are explicitly required by the grammar of ASL. Expressions were absent in approximately 2/3 of required contexts. The omissions ranged across different categories of required expressions. Gail D.'s command of such linguistic facial expressions before her stroke is unquestionable (she is from a deaf family, went to a residential school for the deaf, has deaf children, and married a deaf husband). Her prestroke signing must have been impeccable. In contrast, we have many instances of both syntactic and adverbial markers missing in her poststroke signing, and detail several instances below (Examples 8–11).

In Examples (8) and (9), required syntactic markers are ommitted. In Example (8), Gail D. was signing about the time her hearing aunt, Diane, phoned many times but could not reach her. She signed the English equivalent of "Diane, who is my hearing aunt, waited for a long time, and phoned again and again." The signing was grammatically correct, inflecting the verb signs to reflect temporal aspect. However, her face was blank; the required facial marking for the relative clause was noticeably absent resulting in a sentence which more closely resembles the English sentence "*Diane, hearing aunt, waited for a long time and phoned again and again."

(8) LHD–Gail D.

ASL: *DIANE, HEARING AUNT, WAIT, PHONE[iterative]

English translation: 'Diane, hearing aunt, waited for a long time and phoned again and again.'

<u>Correct</u>: Target sentence correct for context:

$\overline{\text{HEARING AUNT}}^{\text{rel}}$

ASL: DIANE, $\overline{\text{HEARING AUNT}}$, WAIT, PHONE[iterative]

English Translation: 'Diane, who is my hearing aunt, waited for a long time and phoned again and again.'

In Example (9), she was describing her doctor's instructions for taking a particular medication. She reported his instructions: "If there is pain, (take one) morning, noon and night." In ASL conditionals, the linguistic facial expression is required (co-occurring with the antecedent clause), while the manual signal (IF) is optional (Reilly, McIntire, & Bellugi, 1990b). In this case, as in Example (8), Gail D. signed the sentence without the required facial expression for syntactic function in ASL, thus rendering the sentence potentially ambiguous out of context. With the correct conditional facial expression on PAIN, the intended meaning of the sentence is clear.

(9) LHD–Gail D.

ASL: *PAIN++, MORNING, NOON, NIGHT.

English translation: 'Pain morning noon and night.'

<u>Correct</u>: Target sentence correct for context:

cond

ASL: $\overline{\text{PAIN++,}}$ MORNING, NOON, NIGHT.

English Translation: 'If there is pain, (take one), morning noon and night.'

Examples (10) and (11) document instances of omissions of required topicalization and adverbial markers. In (10), Gail D. was describing the severe effects of a hurricane in the town. The particular adverbials and inflections used require specific facial expressions as part of the grammar of the language, but are absent. An example of the appropriate facial marking is provided below.

(10) LHD–Gail D.

ASL: *NEIGHBOR, HER GARAGE COLLAPSE, TREE FELL DOWN[emph].

English translation: 'Neighbor her garage collapse, (and) tree fell down.'

<u>Correct utterance for context</u>:

ASL: $\overset{\text{topic}}{\overline{\text{NEIGHBOR,}}}$ HER GARAGE $\overset{\text{/th/}}{\overline{\text{COLLAPSE,}}}$ TREE FELL $\overset{\text{pom}}{\overline{\text{DOWN}}}$[emph].

English Translation: 'As for my neighbor, her garage disintegrated, and (her) tree slammed down.'

In Example (11), Gail D. described at length her move from one city to another. She said that she and her brother Robert were in the process of moving. They drove for a long time, and then stopped and ate, and then kept on driving until they reached Houston. Gail D. showed no linguistic facial expression at all while signing the sentence.

(11) LHD–Gail D.

ASL: *ROBERT, BROTHER DRIVE++. STOP, EAT
CHICKEN… DRIVE++++ HOUSTON.

English translation: 'Robert (my) brother driving for a long time. (We) stopped to eat chicken. (Then we) kept on driving until we reached Houston.'

The correct utterance for the context with the required linguistic facial expression is shown below:

<u>Correct utterance for context</u>:

ASL: *$\overset{\text{topic}}{\overline{\text{ROBERT, BROTHER}}}$ $\overset{\text{/mm/}}{\overline{\text{DRIVE++.}}}$ STOP, EAT
CHICKEN… $\overset{\text{/mm/}}{\overline{\text{DRIVE++++.}}}$[+] HOUSTON.

English translation: 'Robert, my brother, (and I) were driving for a long time. (We) stopped to eat chicken. (Then we) kept cruising until we reached Houston.'

In all these examples, Gail D. failed to produce the required syntactic and adverbial linguistic facial expressions. This stands in marked contrast to her abundant use of affective facial expressions during signing, and shows selective breakdown of one class of facial expressions following left-hemisphere damage.

A recent case study corroborates our findings of disruption of linguistic facial expressions in deaf signers. Kegl and Poizner (1997) reported a study of a deaf signer, subject N.S., with a left posterior temporal and parietal lobe injury. Like Gail D. this subject often omitted facial expressions signaling sentence-level grammar, specifically topicalization. However, subject N.S., unlike Gail D. was not impaired in his use of facial adverbials. Examination of our data reveal there were 22 instances of omissions of syntatic markers (e.g., topics and relative clauses) and 13 instances of omissions of facial adverbials (e.g., /mm/, /sta/, pursed lips, etc.). As noted, there are significant differences in lesion location in these two signers; Gail D.'s damage is considerably more anterior than N.S.'s Thus these findings may reflect anatomical differences in the execution of facial expression accompanying syntactic versus word level grammar. Additional work is required to further elucidate these functional-anatomical relationships.

Summary. Examining expected/required contexts, each patient shows a marked reduction in the use of one class of facial expressions. With regard to affective facial expressions, right lesioned patient Sarah M. shows numerous examples of missing affective facial expressions, but has relatively well-preserved linguistic expressions, while left-hemisphere damaged patient Gail D. shows the opposite pattern. In the case of Gail D., we note that she uses affective facial expressions freely, perhaps even overexuberantly, but is missing many of the required linguistic facial expressions. We speculate that Gail D.'s overexuberant expressive affect may be functioning as a compensatory device for her linguistic deficits in ASL. The double dissociation between production of affective facial expressions and linguistic facial expressions is an important finding, since one and the same muscular system is involved. Thus, one cannot account for these findings in terms of weakness of facial musculature. These results point toward impairment specific to emotional or linguistic expressivity rather than the control mechanisms of facial movement.

General Discussion

Taken together, these studies provide converging evidence for differential hemispheric control of facial expression production in signers of ASL. Our studies show that asymmetries for linguistic facial expressions in signers evidence greater right-sided intensities. This is a pattern that is the opposite of what is usually reported for affective facial expressions. The well-documented left-sided asymmetries reported for affective expression have been attributed to the greater role of the right-hemisphere in the mediation of affective behaviors. By extension, we believe the right-sided asymmetries observed for linguistic expression reflect left-hemisphere involvement in the execution of these grammatical facial signals. These data are corroborated by case studies of a right-hemisphere lesioned signer and a left-hemisphere lesioned signer. These two cases illustrate a double dissociation in the production of affective and linguistic facial expressions. Together, our findings suggest that cerebral specialization for facial expression production may be driven by the differential functions that these facial emblems serve. These findings may be seen as similar to studies examining prosodic aspects of speech used in the service of emotional versus linguistic contrasts. While the mechanisms for conveying contrastive information in both of these domains may be similar (i.e., changes in F0, stress, duration, etc.) there is some evidence that use of these devices to convey emotion in speech may be dissociated from the ability to use these same devices to convey linguistic contrasts following right- and left-hemisphere damage respectively (Emmorey, 1987; Ross &

Mesulam, 1979; but see also Baum & Pell,1997). This suggestion is compatible with linguistic research indicating that sign language facial expression is analagous to intonation in spoken language (e.g., Wilbur, 1996; Nespor & Sandler, this issue). While the present research has made use of a special class of facial expressions that are observed in ASL, these results have broader implications for theories of neural specialization. Specifically, our findings provide compelling new evidence for the role of functional determinants in the development of cerebral specialization.

REFERENCES

AARONS, D., BAHAN, B., KEGL, J., & NEIDLE, C. (1995). Lexical tense markers in American Sign Language. In K. Emmorey & J. Reilly (Eds.), *Sign, gesture and space* (pp.225–253). Hillsdale, NJ: Lawrence Erlbaum Associates.

BAHAN, B. (1996). *Nonmanual realizations of agreement in American Sign Language.* Unpublished doctoral dissertation, Boston University, Boston MA.

BAKER, C., & COKELY, D. (1980). *American Sign Language: A teacher's resource text on grammar and culture.* Silver Spring, MD: T. J. Publishers, Inc.

BAKER, C., & PADDEN, C. (1978). Focusing on the nonmanual components of American Sign Language. In P. Siple (Ed.), *Understanding language through sign language research* (pp. 27–57). New York: Academic Press.

BAKER-SHENK, C. (1983). *A microanalysis of the nonmanual components of questions in American Sign Language.* Unpublished doctoral dissertation, University of California, Berkeley, CA.

BAUM, S. R., & PELL, M. D. (1997). Production of affective and linguistic prosody by brain-damaged patients. *Aphasiology*, **11**, 177–198.

BETTGER, J., EMMOREY, K., McCULLOUGH, S., & BELLUGI, U. (1997). *Enhanced facial discrimination: Effects of experience with American Sign Language.* Technical Report #INC, Institute for Neural Computation, University of California, San Diego CA.

BOROD, J. C. (1993). Cerebral mechanisms underlying facial, prosodic, and lexical emotional expression: A review of neuropsychological studies and methodological issues. *Neuropsychology*, **7**, 445–463.

BOROD, J. C., & CARON, H. (1980). Facedness and emotion related to lateral dominance, sex, and expression type. *Neuropsychologia*, **18**, 237–241.

BOROD, J. C., HAYWOOD, C. S., & KOFF, E. (1997). Neuropsychological aspects of facial asymmetry during emotional expression: A review of the normal adult literature. *Neuropsychology Review*, **7**, 41–60.

BOROD, J. C., & KOFF, E. (1990). Lateralization for facial emotional behavior: A methodological perspective. *International Journal of Psychology*, **25**, 157–177.

BOROD, J. C., KOFF, E., PERLMAN, M., LORCH, M., & NICHOLAS, M. (1985). Channels of emotion expression in patients with unilateral brain damage. *Archives of Neurology*, **42**, 345–348.

BURT, D. M., & PERRETT, D. I. (1997). Perceptual asymmetries in judgments of facial attractiveness, age, gender, speech, and expression. *Neuropsychologia*, **35**, 685–693.

CAMPBELL, R. (1978). Asymmetries in interpreting and expressing a posed facial expression. *Cortex*, **14**, 327–342.

CAMPOS, J., BARRETT, K. C., LAMB, M. E., GOLDSMITH, H., & STENBERG, C. (1983). Socioemotional development. In P. Mussen (Ed.), *Handbook of child psychology, 2,* Haith, M. & Campos, J. (Eds.), *Infancy and development: Psychobiology* (pp. 783–916). New York: Wiley Press.

COLE, J. (1998). *About face.* Cambridge, MA: MIT Press.

CORINA, D. P. (1989). Recognition of affective and noncanonical linguistic facial expressions in hearing and deaf subjects. *Brain and Cognition*, **9**, 227–237.

CORINA, D. P. (1998a). The processing of sign language: Evidence from aphasia. In H. Whitaker & B. Stemmer (Eds.), *Handbook of Neurolinguistics* (pp. 314–329). San Diego: Academic Press.

CORINA, D. P. (1998b). Aphasia in users of signed languages. In P. Coppens (Ed.), *Aphasia in atypical populations.* Hillsdale, N. J.: Erlbaum.

CORINA. D. P., BAVELIER, D., & NEVILLE H. (1999). Language representation in signers: A comparison of aphasia and fMRI data. *Trends in Cognitive Science*, **12**, 468–470.

CORINA, D., POIZNER, H., BELLUGI, U., FEINBERG, T., DOWD, D., & O'GRADY-BATCH, L. (1992). Dissociation between linguistic and nonlinguistic gestural systems: A case for compositionality. *Brain and Language*, **43**, 414–447.

EKMAN, P., HAGER, J., & FRIESEN, W. V. (1981). The symmetry of emotional and deliberate facial actions. *Psychophysiology*, **18**, 1208–1210.

EKMAN, P., & FRIESEN, W. V. (1978). *Facial action coding system.* Palo Alto, CA: Consulting Psychologist Press.

EKMAN, P., FRIESEN, W., & ELLSWORTH. P. (1982). Conceptual ambiguities. In P. Ekman (Ed.), *Emotion in the human face* (2nd ed). Cambridge, U.K.: Cambridge University Press.

EMMOREY, K. D. (1987). The neurological substrates for prosodic aspects of speech. *Brain and Language*, **30**, 305–320.

FEYEREISEN, P. (1986). Production and comprehension of emotional facial expressions in brain damaged subjects. In R. Bruyer (Ed.),*The neuropsychology of face perception and facial expression.* Hillsdale, N. J.: Lawrence Erlbaum Associates.

GAZZANIGA, M. S., & SMYLIE, C. S. (1990). Hemispheric mechanisms controlling voluntary and spontaneous facial expressions. *Journal of Cognitive Neuroscience*, **2**, 239–245.

GRAVES, R., GOODGLASS, H., & LANDIS, T. (1982). Mouth asymmetry during spontaneous speech. *Neuropsychologia*, **29**, 371–381.

GRAVES, R., LANDIS, T., & SIMPSON, C. (1985). On the interpretation of mouth asymmetry. *Neuropsychologia*, **23**, 121–122.

HAGER, J. C., & Van GELDER, R. S. (1985). Asymmetry of speech actions. *Neuropsychologia*, **23**, 119–120.

HAUSER, M. D. (1993). right-hemisphere dominance for the production of facial expression in monkeys. *Science*, **261**, 475–477.

HICKOK, G., BELLUGI, U., & KLIMA, E. S. (1996). The neurobiology of sign language and its implications for the neural basis of language. *Nature*, **381**, 699–702.

KEGL, J., & POIZNER, H. (1997). Crosslinguistic/crossmodal syntactic consequences of left-hemisphere damage: Evidence from an aphasic signer and his identical twin. *Aphasiology*, **11**, 1–37.

KLIMA, E. S., BELLUGI, U., & POIZNER, H. (1988). Grammar space in sign aphasiology. *Aphasiology*, **2**, 319–328.

LIDDELL, S. K. (1977). *An investigation into the syntactic structure of American Sign Language.* Unpublished doctoral dissertation, University of California, San Diego.

LIDDELL, S. K. (1980). *American Sign Language syntax.* The Hague: Mouton.

LIDDELL, S., & JOHNSON, R. (1986). American Sign Language compound formation processes, lexicalization, and phonological remnants. *Natural Language and Linguistic Theory*, **4**, 445–513.

LOWE, R. C., KEGL, J. A., & POIZNER, H. (1997). Fractionation of the components of role play in a right-hemisphere lesioned signer. *Aphasiology*, **11**, 263–281.

MOSCOVITCH, M., & OLDS, J. (1982). Asymmetries in spontaneous facial expressions and their possible relation to hemispheric specialization. *Neuropsychologia*, **20**, 71–81.

NESPOR, M., & SANDLER, W. (1999) (this issue). Prosody in Israeli Sign Language, *Language and Speech*, **42**(2&3), 143–176.

NEVILLE, H. J., BAVELIER, D., CORINA. D. P., RAUSCHECKER, J. P., KARNI, A., LALWANI, A., BRAUN, A., CLARK, V. P., JEZZARD, P., & TURNER, R. (1998). Cerebral organization for language in deaf and hearing subjects: Biological constraints and effects of experience. *Proceeding of the National Academy of Science*, **95**, 922–929.

PEPERKAMP, S., & MEHLER, J. (1999) (this issue). Signed and spoken language: A. unique underlying system? *Language and Speech*, **42**(2&3), 333–346.

PETRONIO, K. (1993). *Clause structure in American Sign Language.* Unpublished doctoral dissertation, University of Washington.

POIZNER, H., KLIMA, E. S., & BELLUGI, U. (1987). *What the hands reveal about the brain.* Cambridge, MA: MIT Press.

POIZNER, H., BELLUGI, U., & KLIMA, E. S. (1989). Sign language aphasia. In F. Boller & J. Grafman (Eds.), *Handbook of neuropsychology* (pp. 157–172). Amsterdam, The Netherlands: Elsevier Publishers.

REILLY, J. S., & BELLUGI, U. (1996). Competition on the face: Affect and language in ASL motherese. *Journal of Child Language*, **23**, 219–239.

REILLY, J. S., McINTIRE, M., & BELLUGI, U. (1990a). Faces: The relationship between language and affect. In V. Volterra & C. Erting (Eds.), *From gesture to language in hearing and deaf children* (pp. 128–141). New York: Springer-Verlag.

REILLY, J. S., McINTIRE, M., & BELLUGI, U. (1990b). The acquisition of conditionals in American sign language: Grammaticized facial expressions. *Applied Psycholinguistics*, **11**, 369–392.

REILLY, J. S., McINTIRE, M., & BELLUGI, U. (1991). Baby face: A new perspective on universals in language acquisition. In P. Siple & S. Fischer (Eds.), *Theoretical issues in sign language research* (pp. 9–24). Chicago, IL: University of Chicago Press.

RINN, W. E. (1984). The neuropsychology of facial expression: A review of the neurological and psychological mechanisms for producing facial expressions. *Psychological Bulletin*, **95**, 52–77.

ROSS, E. D., & MESULAM, M. M. (1979). Dominant language functions of the right-hemisphere: Prosody and emotional gesturing. *Archives of Neurology*, **36**, 144–148.

SACKEIM, H. A., GUR, R. C., & SAUCY, M. C. (1978). Emotions are expressed more intensely on the left side of the face. *Annals of the New York Academy of Science*, **202**, 424–435.

SKINNER, M., & MULLEN, B. (1991). Facial asymmetry in emotional expression: A meta-analysis of research. *British Journal of Social Psychology*, **30**, 113–124.

VARGHA-KHADEM, F. (1983). Visual field asymmetries in congenitally deaf and hearing children. *British Journal of Developmental Psychology*, **1**, 375–387.

WILBUR, R. B. (1994). Foregrounding structure in ASL. *Journal of Pragmatics*, **22**, 647–672.

WILBUR, R. B. (1996). *Prosodic structure of American Sign Language.* Ms. Purdue University.

APPENDIX 1

FACS coding of canonical affective expressions:

SURPRISE:	AU 1+2+5 (raised brows, widened eyes)
HAPPY:	AU 6+12 (raised cheeks, lip corner pull)
ANGRY:	AU 4+7 (furrowed brow, tightened lower eyelid)

FACS coding of ASL Linguistic Expressions:

Relative clause marker:	AU 1+2+11+26+58
Conditional marking:	AU 1+2+7+55+45
Topic marker:	AU 1+2+56
/th/ adverbial marking:	AU 19+25+41+53
/mm/ adverb marking:	AU 17+22.

Notation Conventions

1. CAT, COME HOME	Glosses for ASL sign string.
2. *The cat, come home*	English translation.
3. …and (her) tree…	Implied referent derivable from context.
4. U-P-S-E-T	Fingerspelled sequence.
5. DRIVE+++	Morphologically inflected form (e.g., temporal inflection).
6. $\overset{\text{rel.cl.}}{\overline{\text{DOG CHASE CAT}}}$	Linguistic facial marker, and scope demarcation.
7. $\overset{\text{((surprise))}}{\overparen{\text{HER HUSBAND COOK DINNER}}}$	Affective facial marker “surprise” and scope demarcation.
8. COOK[Durational]	Inflectional form of the verb “cook.”
9. rel. cl	Relative Clause
10. cond.	Conditional
11. /mm/	Adverbial marker
12. /th/	Adverbial marker
13. pom	Adverbial marker
14. AU 1+2+5	Action Units # 1, 2, and 5.