Hemispheric Mechanisms Controlling Voluntary and Spontaneous Facial Expressions

Michael S. Gazzaniga and Charlotte S. Smylie
Program in Cognitive Neuroscience
Dartmouth Medical School

Abstract

■ The capacity of each disconnected cerebral hemisphere to control a variety of facial postures was examined in three split-brain patients. The dynamics of facial posturing were analyzed in 30-msec optical disc frames that were generated off videotape recordings of each patient's response to lateralized stimuli. The results revealed that commands presented to the left hemisphere effecting postures of the lower facial muscles showed a marked asymmetry, with the right side of the face sometimes responding up to 180 msec before the left side of the face. Commands presented to the right hemisphere elicited a response only if the posture involved moving the upper facial muscles. Spontaneous postures filmed during free conversation were symmetrical. The results suggest that while either hemisphere can generate spontaneous facial expressions only the left hemisphere is efficient at generating voluntary expressions. This contrasts sharply with the fact that both hemispheres can carry out a wide variety of other voluntary movements with the hand and foot. ■

INTRODUCTION

There are a variety of beliefs about how the brain is organized to perceive and produce facial expressions. In the perceptual domain it appears that the right hemisphere has special processes devoted to the efficient detection of upright faces (see Gazzaniga 1989). Although the left hemisphere can also perceive and recognize faces and can reveal superior capacities when the faces are familiar, the right hemisphere appears specialized for unfamiliar facial stimuli (Gazzaniga and Smylie 1983). Interestingly, this pattern of asymmetry has also been shown for the rhesus monkey (Hamilton and Vermiere 1988).

If the right hemisphere is superior for perception of faces, it would be reasonable to suppose it is also specialized for the management of facial expression. Several studies in humans have suggested this to be the case and many rely on what is generally referred to as the "facedness" phenomenon. This phenomenon occurs when photographs of posed faces expressing particular emotions such as fear, disgust, happiness, and so on are split down the middle. Each half of the face is then spliced together at the midline such that two left half faces are combined and two right half faces are combined. It is commonly reported that the composite of the two left half faces appears more emotional (Sackeim and Gur 1978; Sackeim et al. 1978; Heller and Levy 1980). These findings have led to strong claims about which hemisphere is dominant for emotions (Sackeim and Gur 1978; Ekman et al. 1981). Since the left half face is innervated primarily by the right hemisphere, it is postulated that the greater emotionality of the right hemisphere is reflected in the greater left facial response. Similarly, the less expressive right side of the face is innervated by the less emotional left hemisphere.

This simple view of structure–function relations is complicated by further consideration. There is a large literature on the different neural mechanisms that support voluntary as opposed to involuntary facial expression (for review see Rinn 1984). The foregoing studies were carried out on posed faces. When facial composites are made of faces that have spontaneously generated expressions, the "facedness" phenomenon disappears (Ekman et al. 1981). This finding raises many questions about what is meant by brain mechanisms underlying emotional expressions. Spontaneous emotions reflect one level of emotional experience and by the logic of the "facedness" paradigm are generated by each half brain. Brain mechanisms controlling voluntary emotional expressions, on the other hand, involve lateralized processes and again, from the logic of the "facedness" experiments, would appear centered in the right hemisphere. When all of this is considered together, a most complex model emerges for the brain mechanisms controlling emotional expression.

We have recently examined these and related issues in split-brain human patients. Disconnecting the two cerebral hemispheres allows the role the corpus callosum plays in controlling voluntary and involuntary expression to be assessed. It also allows examination of the ability of each hemisphere to initiate facial expressions. To understand the pattern of observed results, it is important to review the known neural mechanism active in controlling both voluntary and involuntary facial expressions.

The pattern of innervation for the upper half of the face is different from that of the lower half of the face and the differences involve both central and peripheral systems. The neural mechanisms involved in voluntary facial postures are controlled by the cortical pyramidal system while the control of spontaneous postures is managed by the extrapyramidal system (Figs. 1 and 2). This diversity of innervation is reported to be responsible for the preservation of symmetrical spontaneous facial postures in the presence of unilateral damage to motor cortex (DeJong 1967). Patients with this lesion will evidence a contralateral facial droop that will resolve when smiling spontaneously. In this instance while the pyramidal input to the facial nucleus is destroyed, the extrapyramidal input is not. It is also commonly reported that patients with extrapyramidal disease such as Parkinson's disease will display a masked face when at rest and then look more normal when smiling to command.

The present study examined the capacity of each cerebral hemisphere to initiate voluntary facial postures. Additional observations were made on spontaneous expressions. The results reveal marked differences in the capacities of each hemisphere to carry out commands, indicating that the corpus callosum plays a critical role in the normal production of voluntary symmetrical facial expressions. Spontaneous expression is unaffected by callosotomy.

RESULTS

Examination of asymmetries in smiling to command revealed marked differences between three split-brain patients and normal controls (Fig. 3). In the former, when the command to smile was lateralized to the left hemisphere, the right side of the mouth dramatically commenced retraction as much as 180 msec before the left side responded. On the majority of the optical frames counted, there was at least a 90 msec difference between the time the right side of the face began its retraction as contrasted with the left side of the face. On some trials after the 90 msec interval there were arguable frames in which after the right-sided movement, the left half face would appear to move. However, in many of these cases this movement seemed to represent physical drag caused by the right-sided movement more than actual left-sided innervation. In the two normals, there was no asymmetry noted in response and each side of the face responded in unison.

When the command to "smile" was presented to the right hemisphere, none of the patients were able to carry out the response (Fig. 4). In another series of tests on Cases JW and DR, a lateralized drawing of a "happy face"

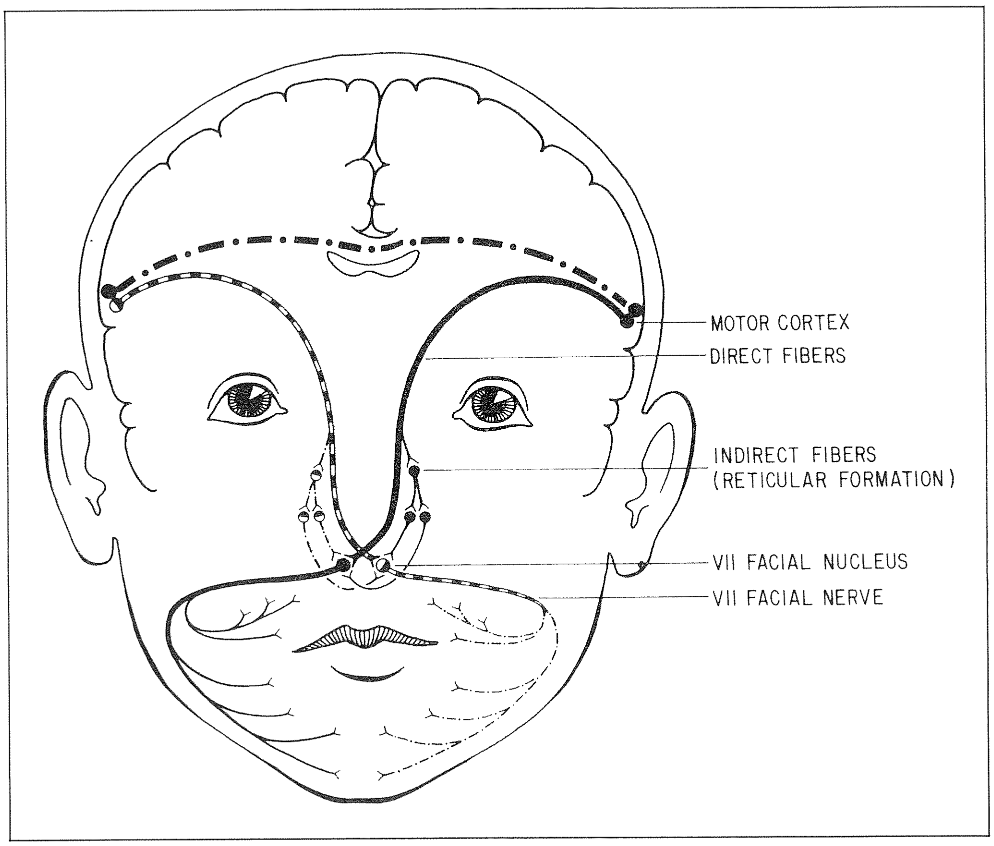

Figure 1. Schematic representation of the known pattern of neural innervation of the lower facial muscles for voluntary facial expressions. The predominantly, direct and contralateral projections of corticospinal nerves to facial nucleus VII are contrasted with the indirect inputs to the ipsilateral facial nucleus.

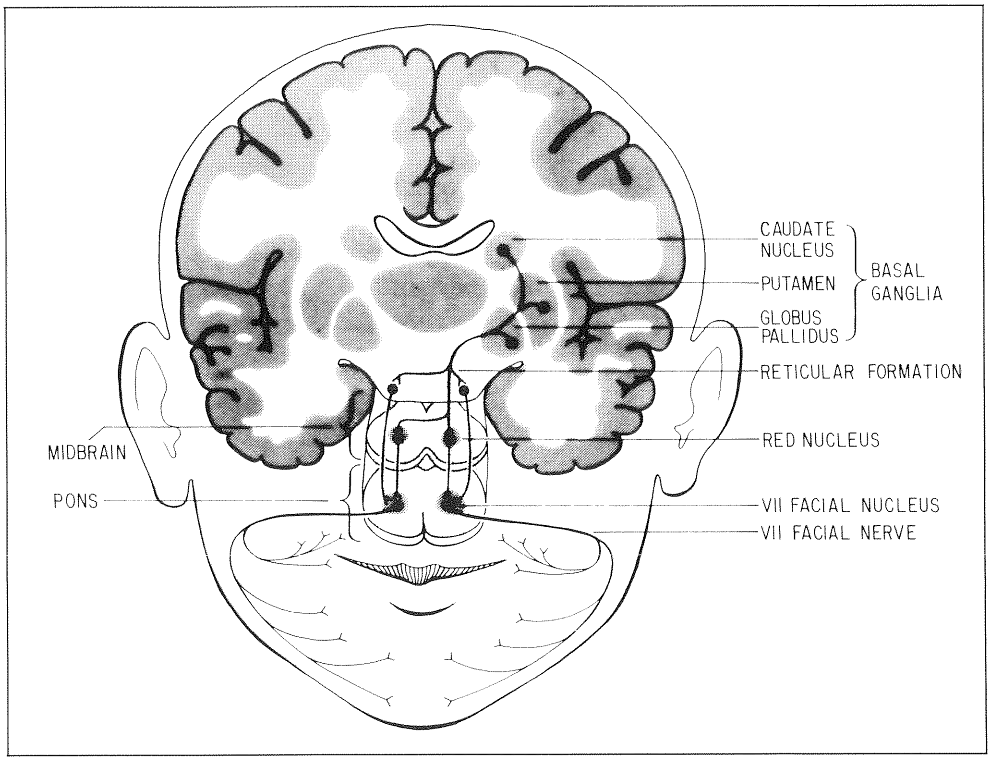

Figure 2. Schematic representation of the known pattern of neural innervation of the lower facial muscles for controlling spontaneous facial expressions. Extrapyramidal systems are involved and control of this system can originate from either hemisphere.

or a "sad face" found the right hemisphere performing at chance. On trials in which an incorrect response had been made, say frowning to a happy face, JW was nonetheless able to draw out a picture of the happy face stimulus with his left hand (Fig. 5). Additionally, no consistent asymmetries were noted on trials in which the left hemisphere responded correctly to the command to "frown." Although there were occasionally indications that the lower right half face showed some earlier posturing, the overall bilateral response of the upper half face masked any consistent pattern.

The inability to elicit those facial expressions contrasted with two of the patient's ability (JW and VP) to carry out other responses such as "wink" and "blow." When the command was given to "wink" to either hemisphere, both patients spontaneously winked the opposite eye. DR, however, was also unable to carry out these commands when they were presented to the right hemisphere. JW and VP were also tested on their ability to "blink" and here both eyes responded to a unilateral command in concert. Finally, however, when the command to "wink" was given to both hemispheres simultaneously only one eye responded and it was usually the right eye. Double commands as a rule were carried out with the left hemisphere's stimulus being honored but not the right.

Analysis of the facial response during spontaneous smiling found both sides of the face responding within one optical disc frame. When spontaneous frowns or looks of puzzlement occurred the upper half of the face (e.g., the brow) also responded symmetrically. The facial asymmetries seen for the command to smile could also be triggered by spoken verbal commands in JW and DR but not VP.

DISCUSSION

The lateralization of neural mechanisms involved in the production and management of facial expressions was investigated in patients who have undergone cerebral disconnection. Careful analysis of optical disc recordings of facial postures revealed that the lower right half face is first to respond when a lateralized command is given to the left hemisphere. On several trials the lag between the right and left half face responses was as long as 180 msec whereas no lags were detectable in normals. This observation, taken together with the fact the right hemisphere could not generate any kind of voluntary facial expression when directly receiving a stimulus, demonstrates that for voluntary expressions, the corpus callosum serves to coordinate the two lateralized motor systems and enables a bilateral response.

It is interesting to consider how the secondary response from the left half face comes about. Because of the callosal section, the command is lateralized to the left hemisphere. The right hemisphere, which controls the "voluntary" aspects of corticopyramidal input for the left half face, is ignorant of the request. This leaves at least two main possibilities for the slow but eventual symmetrical response. The first possibility is that peripheral cues feed back and trigger the right hemisphere to respond through its own corticobulbar system. Arguing

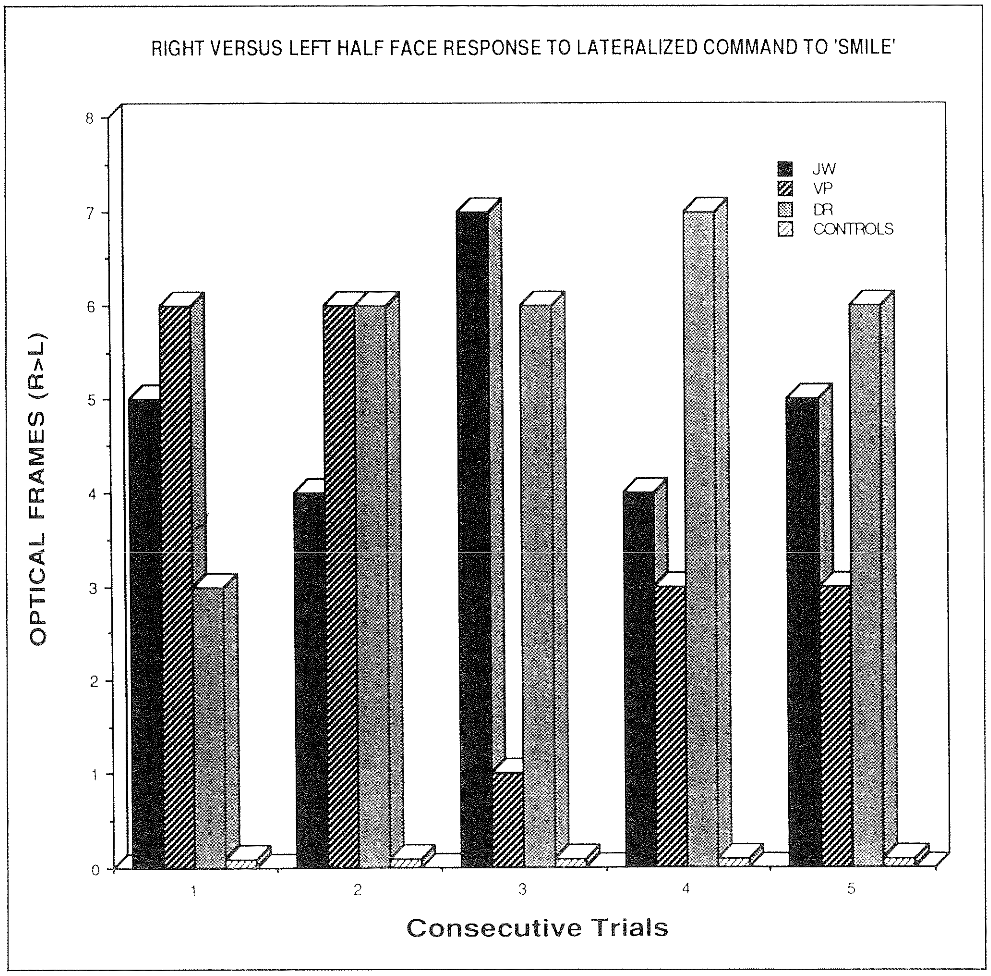

Figure 3. Response latencies to a lateralized command to "smile." Five trials are shown for three split-brain patients and two normals. The time frames refer to the number of optical disk frames that were recorded before the left side of the face joined into the right side response. Both normals were perfectly symmetrical and are plotted as one.

against this notion are a number of factors that include the fact that the facial muscles have few or no muscle spindles (Olkowski and Manchoa 1973; Brodal 1981). It is also not clear that muscle spindle information or other cues from the overlying skin could convey information concerning the type of posture that should be triggered (Dubner et al. 1978).

Another possible mechanism that allows for the ultimate symmetrical response is a rerouting of the signal through the secondary ipsilateral pathways that are known to exist (Courville 1966; Holstege et al. 1977). Here pyramidal cells, through connections with interneurons in brain stem, connect to both facial nuclei. It could well be that the contralateral and quick response is controlled by the direct corticobulbar fibers while the ipsilateral and slower response is controlled by the indirect fibers (Fig. 6). Other motor control systems involving eye–hand coordination in both split-brain monkeys and humans have been reported to function in a related way (Gazzaniga 1970).

Control of the upper half face was possible for two patients by either hemisphere both in terms of the capacity to respond and in the symmetricality of the response. These two patients could carry out the commands to "wink" and to "blink." The command to "wink" always resulted in the contralateral eye responding to the stimulated hemisphere. Taken together these observations would suggest that while the predominant contralateral connections are dominant in controlling response, the prevalent ipsilateral pathways innervating the upper half face that arise from each hemisphere are sufficiently strong to allow for symmetricality when required.

These data also emphasize the difficulty of making structure–function claims based on seemingly lateralized behavioral phenomena. In the past, clear-cut visual field and hand posture data have argued for particular neurological models of visual motor organization (Levy and Reid 1976) that could not be verified with amytal testing (Volpe et al. 1981). Similarly, previous observations of asymmetries in facial expression have led to the inference that the right hemisphere controls voluntary or posed emotional expressions. The present findings suggest that this idea is incorrect. Our results show that the isolated right hemisphere is unable to carry out posed expressions. This observation is consistent with other recent clinical data (Pizzamiglio et al. 1987). Additionally, it is also clear that with the callosum sectioned the dom-

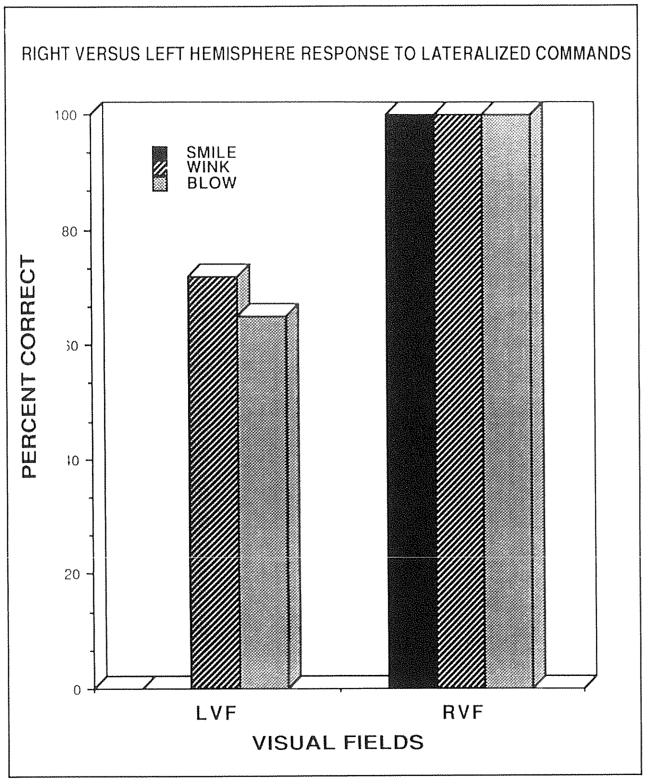

Figure 4. The capacity to carry out commands varied for the right but not the left hemisphere for three split-brain patients. Each response category consists of at least 10 trials. For the wink command, each hemisphere always winked the opposite eye. The right hemisphere was unable to carry out the command to smile.

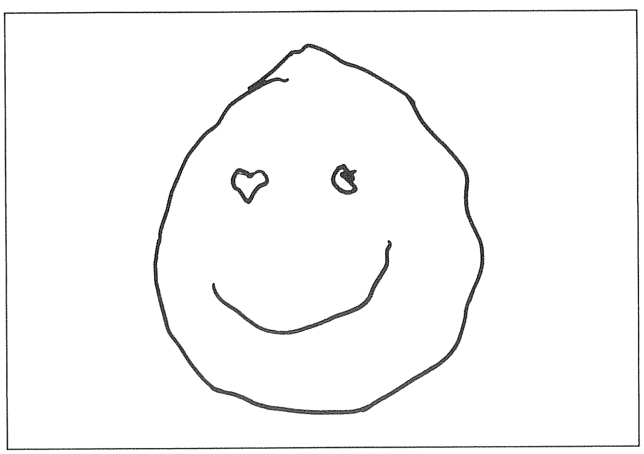

Figure 5. Sample drawing from JW's right hemisphere following a failed attempt to smile to command.

inant pathway for innervation of the face from the left hemisphere involves contralateral neural systems. The left hemisphere directly controls the right face and exercises control over the ipsilateral face through the callosum.

In previous studies we have demonstrated that the right hemisphere is capable of producing involuntary or spontaneous responses such as smiling and laughing (Gazzaniga 1970). In the present study spontaneous episodes were video recorded and analyzed with the optical disc method and no asymmetries in the facial response pattern were observed. It therefore appears that either hemisphere can generate spontaneous emotional events and that, because there are no apparent asymmetries in the facial response, different neural mechanisms are active for these expressions.

It is intriguing to consider why the right hemispheres in these three cases were unable to carry out the command to smile and frown. Except for Case PS, who has unique cognitive structures in his right hemisphere (Gazzaniga et al. 1977), most disconnected right hemispheres in split-brain patients are unable to carry out verbal commands (Gazzaniga 1970). In the present study the right hemisphere failed not only when the command was printed out but also when the command was a graphic that depicted either a "happy" or "sad" face. Yet, many right hemispheres, including all three of the present cases, have the capacity to carry out some kinds of commands. It can respond to requests to move individual digits as well as make hand postures of all sorts (Gazzaniga et al. 1967; Volpe et al. 1982). It can control the upper facial muscles. Why then can it not respond to the command to "smile" or "frown"?

Several studies that examine the cognitive capacity of the right hemisphere have shown it is extremely limited in the kinds of evaluative mental actions it can perform (Gazzaniga and Smylie 1984; Gazzaniga and Miller 1989). Mental operations ranging from making simple inferences to solving simple problems are all outside the cognitive range of the right hemisphere. These kinds of observations emphasize the superiority of the left hemisphere in interpreting events and its dominant role in organizing responses to those events. In the present context, high level evaluative processes must be invoked to override a potentially spontaneous facial expression such as smiling. Such processes would appear to be possible only in the left hemisphere and hence the hemisphere that appears to control voluntary expression. This sort of "voluntary" control would appear different and involve more complex processes than those associated with making "voluntary" hand or foot postures in response to a cue. Therefore, where evaluations involve more psychological aspects of a person's expressions, the left hemisphere appears dominant.

It remains to determine what "facedness" phenomenon reflect. It is not present in children (Ladavas 1982). As already described the composite faces must be made up from pictures of adult posed faces. Perhaps in the normal brain the pattern of neural activity that innervates the left half face through the callosal link creates a facial posture, on creation of the artificial composite, that "looks" more emotional than a right half face composite. Yet, it would appear that the phenomenon relates to

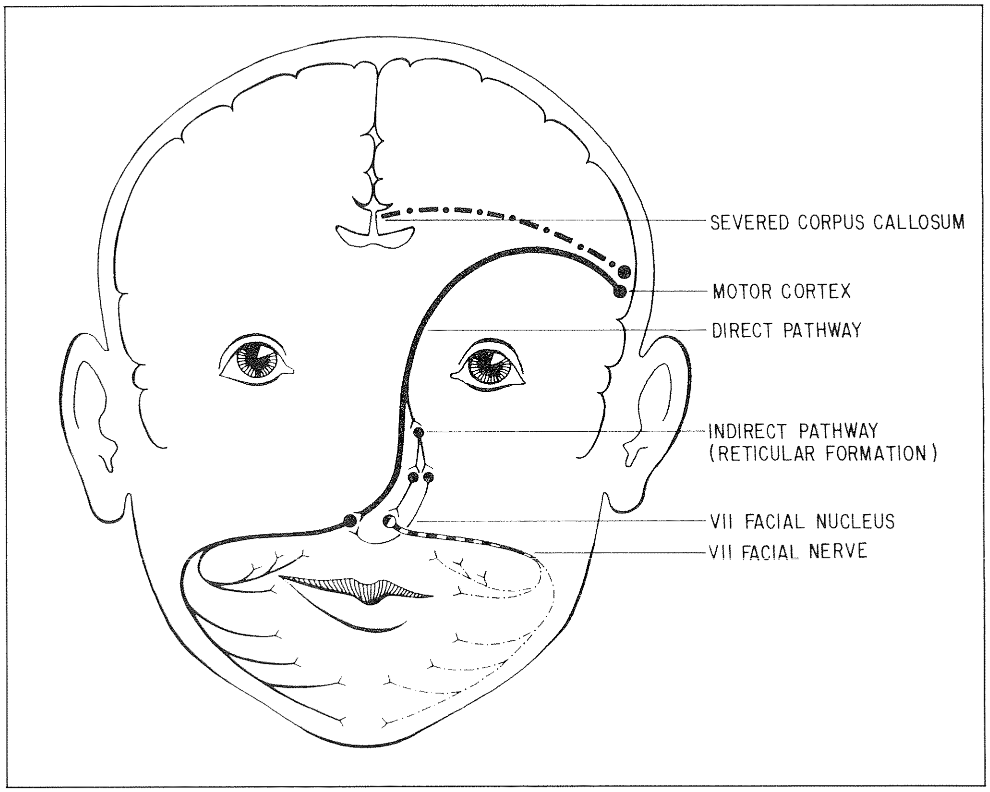

Figure 6. When a callosum sectioned patient attempts to carry out a voluntary command lateralized to the left hemisphere, a marked asymmetry can be observed. The neural mechanism responsible for this is depicted.

nothing real in terms of brain mechanisms or psychological reality.

METHODS

Subjects

Three patients who have undergone commissurotomy were examined. JW, VP, and DR have all been extensively studied and their medical histories have been reported elsewhere (Gazzaniga et al. 1984b; Baynes 1990). JW underwent staged callosal section at the age of 26. MR scans have shown that JW's callosum is severed completely. Earlier evaluations of JW have shown that he has little or no capacity to cross-compare perceptual information between his two disconnected hemispheres.

DR underwent a single operation. MR reveals a complete section of the callosum. She too shows no capacity to transfer visual or tactile information. She is able to carry out visual match-to-sample tasks for lateralized visual stimuli but her capacity to understand language in the right hemisphere is extremely limited.

VP was operated on in two stages. Her MR scan revealed some spared fibers in both her splenium and rostrum of the corpus callosum. Yet she has not shown any evidence of interhemispheric interactions on routine and frequent tests of visual perception. There has been no suggestion of transfer or cross-integration of information on tests examining her capacity to compare whether or not two simple stimuli, one presented to each half field, are the same or different. Similarly, she has performed at chance when required to decide whether two words presented to the different hemispheres were semantically related or not. Even though VP evidently has some visual fibers remaining she performs at chance in many tests of visual interaction (Gazzaniga et al. 1984b; Fendrich and Gazzaniga 1988).

It is important to note that both JW and VP are among a small group of split-brain patients who have the capacity to comprehend language in the right hemisphere. As already noted, DR also has only a rudimentary capacity to comprehend language. VP has, in addition, demonstrated the capacity to generate speech out of both hemispheres.

For controls, two right-handed males of similar age to the patients were tested in the same testing arrangement just described.

All patients and controls were videotaped using a digital camera during all testing sessions. The camera was placed behind a computer-driven monitor for the presentations of lateralized visual stimuli. A full face recording was made during all testing sessions. Subsequent to the test session the videotape was edited for extraneous time delays and the experimental time on the videotape was transferred to an 8-in. optical disk recording system (Panasonic TQ-2-26F). In this fashion the videotape could be reduced to a series of 30-msec discrete images that could be analyzed. Thus, a 1-sec episode on tape would render 33 individual images. In practice, movement patterns that in many instances were not discernible with video recording became easily and immediately observable when played back on the optical disc system. In general the frames showing movement of the right and left side of the face were noted. The difference between right and left response was then calculated. Pilot studies revealed the command to "smile" produced the clearest opportunity to assess asymmetrical processes. Commands such as "blow" and "frown" do not so uniquely draw on the lower facial muscle groups.

For each set of observations, the patients were placed 62 cm from the computer monitor that was driven by an Apple IIe computer. A set of commands was then randomly presented to either the left or right visual field at 150 msec. The stimuli appeared no closer than one degree to the visual midline. In tests in which line drawings of face postures were presented to one or the other hemisphere, a Macintosh computer was used with a graphic display program that limited the lateralized presentation of a stimulus to 150 msec.

Experimental runs varied from 5 to 10 min and were run over several days of examination in an effort not to routinize the limited sets of commands used. To obtain the measurements on the facial postures during spontaneous smiling, recordings were made while the patient was conversing with the examiner. Usually following an appropriate malapropism of the examiner the desired spontaneous smile was evident and could then be used for graphic analysis.

Acknowledgments

Aided by NIH Grant 5-PO1 NS17778-08, Javits Investigator Award 5 Ro1-NS22626, and the James S. McDonnell Foundation

REFERENCES

Baynes, K. (1990). Language and reading in the right hemisphere: Highways or byways of the brain? *Journal of Cognitive Neuroscience*, *2*, 159–179.

Brodal, A. (1981). *Neurological Anatomy: In Relation to Clinical Medicine*. New York: Oxford University Press.

Courville, J. (1966). Retrobulbar fibres to the facial nucleus and the lateral reticular nucleus. *Brain Research, 1*, 338–354.

DeJong, R. N. (1967). *The Neurological Examination*. New York: Hoeber Medical Division, Harper & Row.

Dubner, R., Sessle, B. J., & Storey, A. (1978). *The Neural Basis of Oral and Facial Function*. New York: Plenum.

Ekman, P., & Friesen, W. (1975). *Unmasking the Face*. New York: Prentice Hall.

Ekman, P., Hager, J. C., & Friesen, W. V. (1981). The symmetry of emotional and deliberate facial actions. *Psychophysiology, 18* (2), 101–106.

Fendrich, R., & Gazzaniga, M. S. (in press). Hemispheric processing of spatial frequencies in two commissurotomy patients. *Neuropsychologia*.

Gazzaniga, M. S. (1970). *The Bisected Brain*. New York: Appleton-Century-Crofts.

Gazzaniga, M. S. (1989). Organization of the human brain. *Science, 245*, 947–952.

Gazzaniga, M. S., & Miller, G. A. (1989). The recognition of antonym by a language-enriched right hemisphere. *Journal of Cognitive Neuroscience*, *1*, 187–193.

Gazzaniga, M. S., & Smylie, C. S. (1983). Facial recognition and brain asymmetries: Clues to underlying mechanisms. *Annals of Neurology, 13*, 536–540.

Gazzaniga, M. S., & Smylie, C. S. (1984). Dissociation of language and cognition: A psychological profile of two disconnected right hemispheres. *Brain, 107*, 145–153.

Gazzaniga, M. S., LeDoux, J. E., & Wilson, D. H. (1977). Language, praxis, and the right hemisphere: Clues to some mechanisms of consciousness. *Neurology, 27*, 1144–1147.

Gazzaniga, M. S., Nass, R., Reeves, A., & Roberts, D. (1984a). Neurologic perspectives on right hemisphere language following surgical section of the corpus callosum. *Seminars in Neurology, 4*, 126–135.

Gazzaniga, M. S., Smylie, C. S., Baynes, K., Hirst, W., & McCleary, C. (1984b). Profiles of right hemisphere language and speech following brain bisection. *Brain and Language, 22*, 206–220.

Hamilton, C. R., & Vermeire, B. A. (1988). Complementary lateralization in monkeys. *Science*, *242*, 1691–1694.

Heller, W., & Levy, J. (1980). Perception and expression of emotion in right-handers and left-handers. *Neuropsychologia, 19*, 263–272.

Holstege, G., Kuypers, G. H. J. M., & Dekker, J. J. (1977). The organization of bulbar fibre connections to the trigeminal, facial and hypoglossal motor nuclei. *Brain, 100*, 265–286.

Ladavas, E. (1982). The development of facedness. *Cortex, 18*, 535–545.

Levy, J., & Reid, M. (1976). Variations in writing posture and cerebral organization. *Science, 184*, 337–339.

Olkowski, Z., & Manocha, S. L. (1973). Muscle spindles. In G. H. Bourne (Ed.), *The Structure and Function of Muscle* (2nd ed). New York: Academic Press.

Pizzamiglio, L., Caltagirone, C., Mammucari, A., Ekman, P., & Friesen, W. V. (1987). Imitation of facial movements in brain damaged patients. *Cortex, 23*, 207–221.

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

Sackheim, H. A., & Gur, R. C. (1978). Lateral asymmetry in intensity of emotional expression. *Neuropsychologia, 16*, 473–481.

Sackheim, H. A., Gur, R. C., & Saucy, M. C. (1978). Emotions are expressed more intensely on the left side of the face. *Science, 202*, 434–436.

Volpe, B. T., Sidtis, J. J., & Gazzaniga, M. S. (1981). Can left-handed writing posture predict cerebral language laterality? *Archives of Neurology, 38*, 632–633.

Volpe, B. T., Sidtis, J. J., Holtzman, J. D., Wilson, D. H., & Gazzaniga, M. S. (1982). Cortical mechanisms involved in praxis: Observations following partial and complete section of the corpus callosum in man. *Neurology, 32*, 645–650.