Examining Frontal Lobe Functions and their 'Family Resemblance'

Valerie Carver

The frontal lobes constitute approximately one-third of the total brain area. It is not surprising then to learn that the frontal lobes are important in a variety of functions. Research has shown us that the frontal lobes play a role in motor functions, divergent thinking, environmental control of behavior, temporal memory, spatial orientation, social behavior, olfaction, and face movements. Given this wide variety of functions, researchers have found it a difficult and puzzling task to tie them together into some sort of coherent framework that would describe an overall function of the frontal lobes. Is there any sort of 'family resemblance' among these different functions? Are these various functions related in some way? Throughout this paper I will first discuss the functions of the frontal lobes and second discuss the 'family resemblance' among these functions.

Functions of the frontal lobes

Motor functions

The primary motor cortex is located within the frontal lobes. Damage to this area undoubtedly results in some motor deficits. Specifically, damage to the primary motor cortex often results in impaired ability to make fine movements with the fingers. In addition, controlateral limb movement is also impaired. An example of such an impairment would be a difficulty in playing the piano.

Patients with frontal lobe lesions may have also lesions to the supplementary motor cortex. Such lesions produce problems in ordering and executing sequences of behavior. Such impairments would make it difficult for patients to copy a series of facial movements in the correct order.

Other research has shown us that the frontal lobes play an important role in voluntary gaze (control of the eyes), for example visual searching. Thus, frontal lobe patients are unable to focus on the whole environment at
once, rather they focus on a particular portion of the surrounding environment.

Corollary discharge refers to a signal that keeps the world around us still while we move. Damage to the frontal lobes may cause deficits in corollary discharge, resulting in the inability to communicate to the rest of the brain that one is moving. Thus when one moves around in the environment, the world would move with them instead of staying constant.

Broca’s area, the third frontal convolution of the left hemisphere, is the locale for speech production. Thus damage to Broca’s area results in difficulty with speaking. It is important to note, however, that the damage is not to the speaking muscles themselves.

**Divergent thinking**

Divergent thinking refers to thinking in which deriving a variety of solutions is desirable, as opposed to one “right” answer. This sort of thinking is useful in brainstorming and in problem solving. Frontal lobe lesions have been found to impair divergent thinking abilities. Problem solving abilities may consequently be impaired in these patients. The difficulty arises when attempting to generate new solutions to a problem.

Frontal lobe patients also show deficits in behavioral spontaneity, which includes fluency of speech and spontaneity of facial expressions and movements. So when these patients are asked to list all of the words they can think of that start with a particular letter, they are impaired in contrast to normals.

**Environmental control of behavior**

The use of environmental cues to guide behavior is impaired in frontal lobe patients. Frontal lobe patients have difficulties shifting response strategies, thus resulting in inflexible behavior. When engaged in a task that requires changing strategies, these patients are unable to do so, and stick to the first strategy they implemented. These patients are also apt to disregard task instructions and take risks.

**Temporal memory**

Temporal memory refers to memory for an event that has occurred as well as memory for the sequence of events (recency memory). Frontal lobe lesions can cause deficits in judging the recency of events and items. So when asked how to do laundry, for example, frontal lobe patients may not remember what to do first, second, and so on, even though they are completely capable
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of performing the different steps. Similarly, they often show impairments in judging the number of times they have seen a particular stimulus, or the frequency of that stimulus.

In tasks of delayed alternation and delayed response, frontal lobe patients are also impaired. Delayed alternation and delayed response tasks involve presenting a reward in some particular location, and then imposing a delay before they can respond. Frontal lobe patients are unable to remember the location of the reward after a delay.

Spatial Orientation

Lesions to the frontal lobes may result in impaired egocentric spatial relation, or personal orientation. Thus, although these patients may be fine when asked to follow maps, they are impaired at pointing to their own body parts that correspond with the body parts labeled in a drawing.

Social Behavior

Frontal lobe patients often show marked changes in personality, exhibiting pseudodepression and pseudopsychopathy. Pseudodepression is most often exhibited when there are lesions to the left frontal lobe. Characteristics of pseudodepression include apathy, and in general exhibiting little emotion or interest. Pseudopsychopathy, on the other hand, is most often exhibited after lesions to the right frontal lobe. The characteristics of pseudopsychopathy are quite different from those of pseudodepression, including exhibiting tactless, promiscuous behavior, and a general increase in impulsive motor activity.

Olfaction

When the orbital-frontal cortex, probably the central olfactory cortex, is damaged, difficulties arise in discriminating among different smells. Frontal lobe patients, however, are not impaired at olfactory detection.

Face Movements

Although the face area of the frontal lobes controls sensory and motor control of the face, lesions to the frontal lobes most often result in impairments in spelling, phonetic discrimination, and fluency of speech. It is interesting, however, that facial expressions are spared in these patients.
'Family resemblance' of the functions of the frontal lobes

As may be obvious after reading the previous section of this paper, the frontal lobes are far from homogeneous in their functioning. It is no wonder that researchers have been consistently puzzled with trying to consolidate the diverse functions of the frontal lobes into a meaningful and coherent framework. In the next section of this paper I intend to make some sense out of this wide array of functions of the frontal lobes.

Teuber (1964) suggested that frontal lobe functions can be classified as compensatory mechanisms that allow one to carry out high-level motor functions in response to sensory input. He based much of this generalization on the function the frontal lobes play in corollary discharge and voluntary gaze. Recall that corollary discharge allows one to move around in the world and yet see the world as constant, not moving. Corollary discharge signals the sensory system that movements will be taking place. Thus impairments to corollary discharge result in difficulties associated with maintaining a still and stable environment. It is plausible, then, to assume that corollary discharge plays a key role in nearly all motor functions. Walking, clearly a motor behavior, relies on corollary discharge so that when one moves around in the environment the surroundings stay still. Less obvious motor functions, such as talking, also rely on corollary discharge. Talking involves movement of the face, and movement of the head without corollary discharge would also result in a moving environment. Facial expressions may not require corollary discharge, as they are movements within the head and may not cause a shift in the environment. Recall, as previously discussed, that facial expressions are spared with damage to the frontal lobes. So, this discussion of corollary discharge helps support the finding that facial expressions are not impaired with lesions to the frontal lobes.

Voluntary gaze refers to the ability to search around a visual field. Therefore, deficits in voluntary gaze produce a sort of inflexibility in visual searching.

In more general terms, corollary discharge and voluntary gaze are prominent players in the intake of sensory information, helpful in preparing one to engage in motor function. The role of voluntary gaze is perhaps more broad than that of corollary discharge in that one must often perceive the surrounding environment before being able to act on that environment. Corollary discharge is the mechanism by which we can act in our environment without it changing.

The question that still remains to be addressed, however, is whether the various functions of the frontal lobes can fit into this framework proposed by Teuber (1964). That is, are all of the functions of the frontal lobes explained by the generalization that they allow one to carry out high-level motor functions
by controlling response to sensory input? Do corollary discharge and voluntary gaze play an important role in all frontal lobe functions? I will now address these questions.

On a preliminary note, it appears that many of the frontal lobe functions do in fact appear to involve reading sensory input and using that input to influence motor behavior: motor functions, environmental control of the behavior, spatial orientation, and facial movements. However, there are other frontal lobe functions that do not adequately fit into this framework: divergent thinking, temporal memory, social behavior, and olfaction. Since Teuber's work in 1964, there has been discovery of many more frontal lobe functions. Due to the advanced knowledge of frontal lobe functions, I propose a refinement of Teuber's (1964) hypothesis.

Expanding Teuber's hypothesis

From an evolutionary standpoint, the frontal lobes were the last portion of the brain to evolve. In comparison with animals, humans have larger frontal lobes and also respond to the environment in more distinct ways. For example, humans have highly developed language, whereas animals do not have such an intricate language system. As much of the earlier research on the frontal lobes was presumably done with animals, researchers were unable to see all of the functions of the frontal lobes. They were more likely to observe motor deficits rather than other deficits in responding to the environment. This explanation helps explain why Teuber's (1964) hypothesis might fail to account for some of the alternative ways of responding to the environment.

Frontal lobe functions appear similar in that they influence how one responds to his/her immediate environment. The means by which the frontal lobes influence one's response to his/her environment is by influencing the intake of sensory stimuli. Frontal lobe patients appear to have difficulty keeping proper track of sensory inputs. Whereas Teuber (1964) hypothesized that the frontal lobes use incoming sensation to help one engage in high-level motor behavior, my hypothesis is actually simpler. I propose that the frontal lobes use incoming sensations to help one react to their environment, not necessarily just engage in high-order motor functions. This hypothesis would account for motor functions of the frontal lobes, divergent thinking, environmental control of behavior, temporal memory, spatial orientation, and face movements.

Consider first the motor functions of the frontal lobes. As corollary discharge and voluntary gaze were previously discussed in some detail, I will discuss the other motor functions associated with the frontal lobes. The ability to produce fine motor movements with the limbs and fingers is an important way of responding to your environment. For example if you want
to pick up a pencil, you must be able to use your fingers precisely enough to first grasp the pencil, and then pick it up. Frontal lobe patients with impairments in ordering behaviors are having difficulty using the sensory information they are supplied with in an efficient manner. Thus, even though they may be seeing clearly a set of facial movements they are to copy, they are unable to order them correctly when they actually do copy them. Speech deficits may arise because the patient is unable to speak the knowledge they have.

Divergent thinking may also apply to this framework. Problem solving difficulties, the inability to generate alternative solutions, may be due to the patient’s impairment in taking a small problem (sensory input) and elaborating on it. Thus frontal lobe patients have trouble taking sensory input and using that input to generate responses. For example, a frontal lobe patient may enter a room and notice that it is too hot. However, the patient fails to think of the numerous alternatives to fixing the problem: turning on the fan, opening the window, keeping the door open, or turning on the air conditioning. Although these patients may be completely able to do the behaviors, their deficit lies in the ability to think of them as possible solutions to the problem. Clearly problem solving is a prominent part of one’s daily life. Similarly, behavioral spontaneity in frontal patients is markedly decreased. This closely ties into the discussion of problem solving. Patients are unable to come up with more than one way to respond to the environment.

Controlling behavior, another function of the frontal lobes, involves adjusting behavior to the incoming sensory stimuli from the environment. This explains why behavior may become rigid and inflexible. Once a frontal lobe patient has begun to engage in behavior, subsequent sensory stimulation is not processed adequately enough to cause a shift in behavior.

Temporal memory deficits imply that the sensory information present at a particular time is not being correctly processed. Consequently, the sensory information is jumbled in memory and not stored in order of occurrence. When the time comes that one with frontal lobe lesions must recall this information, the order it is recalled is random. The inability to store sensory information about events would certainly influence how these people react to their environment.

Spatial orientation deficits in frontal lobe patients reflect their inability to relate sensory stimuli to themselves in a proper fashion. Thus when shown a drawing of a human being and the hand is pointed out, these patients are impaired at relating that information to their own store of information.

Frontal lobe lesions result in impairments in spelling, phonetic discrimination, and fluency of speech. These deficits may result from a jumbling of sensory information, and an inability to organize and process the information efficiently. Frontal lobe patients may hear and understand the meaning of a word, but when asked to spell it they are unable to use the sensory information (auditory, in this case) to produce the correct spelling.
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Limitations of the proposed theory

This theory, like most, has its limitations and drawbacks. First, the theory is very general, and consequently difficult to test. Second, there are frontal lobe functions that are not easily accounted for by this theory: social behavior and olfaction.

Consider first social behavior. If one has difficulty in relating to his/her environment, the result could very possibly be a change in personality. The inability to respond appropriately to one’s environment is no doubt a very frustrating occurrence. One may respond in a few ways. First, this frustration may cause the person to feel inadequate, causing pseudodepression. Second, the frustration could spark more and more severe attempts to function appropriately, resulting in impulsiveness or pseudopsychopathy. Although this is a possibility, there is no conclusive evidence to support this assumption, and this hypothesis remains mere speculation.

Like social behavior, olfaction is not easily explained as a function that helps one respond to his/her environment. Impaired olfactory discrimination involves the inability to differentiate between sensory inputs, in this case different smells. It is hard to say how this influences one reaction to his/her environment, but it is likely that not discriminating between different smells causes the environment to seem much more homogenous than it in fact is. Again, this hypothesis is completely unsupported and tentative.

Conclusions

While reading this paper, one may note that there is certainly a fair amount of ambiguity in discussing the frontal lobes. There is currently no clear and coherent theory for frontal lobe function. I have proposed a refinement of an older theory (Teuber, 1964), however this theory has its limitations. Despite these limitations, the proposed theory does account for a majority of the frontal lobe functions, and is an important beginning to developing a coherent theory for their function. Perhaps with more precise knowledge of the frontal lobes and their specific functions, one may find the task of drawing together the functions somewhat easier. Researchers in the future may want to focus first on specifying with more precision the functions of the frontal lobes, and then on devising new ways to tie this information together with the old.

References


Notes