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LATERALIZATION OF HEDONIC RESPONSES TO ODORS IN INDIVIDUALS WITH UNILATERAL HEMISPHERIC LESIONS

by

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A dissertation submitted to the Graduate Faculty in Psychology in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York

1998

This manuscript has been read and accepted for the Graduate Faculty in Psychology in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

1/12/98
Date

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Abstract

LATERALIZATION OF HEDONIC RESPONSES TO ODORS

IN INDIVIDUALS WITH UNILATERAL HEMISPHERIC LESIONS

by

Nancy K. Madigan

Advisors: Professors Joan Borod and Howard Ehrlichman

Although there is evidence suggesting the existence of hemispheric asymmetries for emotion, the nature of cerebral lateralization has been the source of much debate. Several theories have emerged, suggesting different roles of the right and left hemispheres in emotional processing. In the current study, affective behaviors elicited in response to pleasant and unpleasant odors were examined in individuals with left hemisphere lesions (LHD) and right hemisphere lesions (RHD), and in demographically-matched normal control participants (NC). Responses to odors consisted of: (1) spontaneous facial expressions; (2) prompted facial expressions (representing the participant's odor experience); (3) presence of avoidant/withdrawal responses (e.g., head turning behaviors); (4) subjective ratings of the odors' pleasantness/unpleasantness; and (4) a behavioral choice measure.

Facial expressions evoked by odors were compared to expressions elicited without odors, including posed hedonic expressions and emotional expressions. All expressions were evaluated by naïve judges. Non-emotional facial factors, such as paralysis and buccofacial apraxia, were also examined to control for these factors.

Ratings of both spontaneous and prompted facial expressions evoked to odors, as well as posed hedonic expressions elicited without odors, indicated that no compelling differences emerged between LHDs, RHDs, and NCs. However, for posed emotional facial expressions, RHDs' expressions were rated as less accurate and less intense than expressions produced by NCs. Subjective ratings of odors suggested that RHDs perceived odors presented to the right nostril as less intense in comparison to NCs. Lastly, more avoidant responses were produced by LHDs than by RHDs and NCs.

For facial expressions, comparisons among the different elicitation methods suggest that right neocortical regions may be involved in higher level, symbolic aspects of emotional processing. Findings for hedonic experience, assessed by subjective ratings, also indicated the importance of the right hemisphere in experience of hedonic intensity. Finally, findings regarding the enhanced presence of avoidant responses in the LHD group might be explained by a possible contralateral disinhibition of right hemisphere functions (i.e., withdrawal action tendencies) following left-hemisphere lesions. Overall, these findings support the notion of right-hemisphere predominance in certain aspects of emotional processing, but suggest that affective information may not be lateralized along a hedonic dimension.

ACKNOWLEDGEMENTS

Several individuals have been quite instrumental in the conceptualization and guidance of this project, as well as in furthering my development as a scientist and a clinician. First, I would like to thank the co-chairs of my committee, Joan Borod and Howard Ehrlichman. Through their different approaches, they have taught me the value of focusing on both the "forest" (relating our findings to theoretical issues in emotion and brain functioning) and on the "trees" (developing a sound methodological approach to research). I greatly appreciated their insight, encouragement and support throughout the project. I would also like to thank Jim Tweedy for his assistance and sage advice, as well arranging the major source of participants for the study. I would also like to thank my outside readers, Aliza Brozgold and Avery Gilbert, for their gracious willingness to help with this project.

I have been fortunate to have known a number of students throughout my graduate training who have become and will remain both friends and colleagues: Sandra Brown, Ronny Geva, Hulya Erhan, Ilana Grunwald and Conni Haywood. Their help, support, insight, encouragement and friendship have meant a great deal to me. I would also like to thank my fellow students from Dr. Borod's lab for their help and reassurance, which I hope I can repay. I would especially like to thank Jacqui LoBosco for her unflinching help in the less glamorous aspects of the project (i.e., data entry), as well as for helping me maintain my sanity while editing a never-ending series of videotapes. My parents' and family's encouragement throughout my graduate studies was greatly appreciated.

Finally, I would like to thank my husband, Don O'Malley, who buoyed my spirits when my enthusiasm and mood ebbed, who knew when to give advice and (most of the time) when to listen, who served as my toughest critic and my best advocate in developing ideas, and who never complained for what was given up or put off in order to complete my graduate degree. With his support, he made me realize that what I initially thought impossible was indeed possible.

This project was supported by NIMH Grant No. MH-44889, and Professional Staff Congress (PSC-CUNY) Research Awards, Nos. 665219 and 666249. It was also supported in part by Grant No. 5 MO1 RR00071 for the Mount Sinai General Clinical Research Center from the National Center for Research Resources, National Institutes of Health.

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INTRODUCTION

Overview

Researchers have attempted to understand the neuroanatomical basis of emotion by a number of different paradigms and by examining emotional processing in normal, neurological and psychiatric populations. The limbic system plays an important role in emotional processing, as evidenced by a number of studies examining changes in emotional and motivational behavior following selective damage or stimulation of limbic structures (for review, see Joseph, 1990). As there are extensive interconnections between the limbic and cortical systems (Barbas, 1995), recent research has focused on the role of neocortical structures in emotional processing (e.g., Kolb & Taylor, 1990). Elucidating these neuroanatomical substrates has been difficult, as several components are involved in emotional processing, including perception of the stimulus, arousal, experience of the emotion, emotional expression, and goal-directed, action-oriented activities (Plutchik, 1984). It is likely that these components involve the activity of multiple neural systems.

Using various methods and different patient populations, many neuropsychological studies have explored the role of hemispheric involvement in emotional and affective behavior. Such studies have focused on the appreciation of emotional stimuli and the expression of emotions via different communication channels (e.g., facial expression, prosody). In addition, hemispheric asymmetries in arousal and emotional experience have been examined. Yet, exactly how emotional behaviors are lateralized is debated.

Several neuropsychological theories regarding lateralized contributions to emotional processing have been suggested. These theories focus on different dimensions of emotion and

propose hemispheric differences in terms of emotional valence (positive versus negative emotions), as well as the outcome of emotional states associated with approach and withdrawal (Davidson & Tomarken, 1989; Kinsbourne & Bemporad, 1984). Two theories which have received much attention are the right hemisphere and valence hypotheses. The right hemisphere hypothesis suggests a right-hemisphere dominance in processing both positive and negative emotions (Borod, Koff & Caron 1983; Bryden & Ley, 1983; Heilman & Bowers, 1990; Ross, 1985). The valence hypothesis asserts that the cerebral hemispheres are differentially involved in emotional processing, with a left hemisphere specialization for positive emotions, and the right hemisphere, for negative emotions (Davidson, 1984; Dimond & Farrington, 1977; Dimond, Farrington, & Johnson, 1976 Fox, 1991; Hirshman & Safer, 1982; Sackeim et al., 1982).

Other investigators have focused on the role of action dispositions, or approach versus withdrawal processes, in emotion (Davidson, 1993; Davidson, Ekman, Saron, Senulis & Friesen, 1990; Fox, 1991; Kinsbourne & Bemporad, 1984). These researchers have proposed that the left hemisphere is involved in approach-related affective behaviors and the right hemisphere in affective behaviors related to withdrawal and avoidant responses. Support for such theories has come mainly from work examining electroencephalogram (EEG) activation in infant and normal adults using various mood-induction methods. Usually a motoric signal, a facial expression or a gestural act, is used to mark the occurrence of the emotional state. This theory regarding action tendencies is not necessarily exclusive of those hypotheses which take into account emotional valence. Certain emotions, such as fear or disgust, are prototypically withdrawal-related emotions, with fear expressed by escape behaviors and disgust by avoiding

or withdrawing from sensory stimuli. However, anger can accompany approach or withdrawal action tendencies (for discussion, see Davidson, 1994).

Neuropsychological studies have used subjects with unilateral brain lesions to clarify the nature of the differential hemispheric involvement in the various components of emotional behavior. Several studies have examined perception and expression of emotion in such patients (for reviews, see Borod, 1992, 1993). In terms of exploring alterations of withdrawal/avoidant responses in such patients, Mammucari et al. (1988) found that patients with right-hemisphere lesions made fewer gaze aversions when viewing a distressing film than subjects with left-hemisphere lesions and age-matched controls. This finding supports the idea that the right hemisphere may be preferentially involved in producing withdrawal-related actions, but this finding has not been replicated. Site of lesion location also appears to be an important factor in producing mood disturbances (see reviews by Sackeim, 1991; Starkstein & Robinson, 1989, 1994), although some findings are equivocal (see Gainotti, 1989). Similarly, shorter-lasting changes in emotional responses as a function of hemispheric damage have been described. For instance, patients with left-hemispheric lesions were noted to have "catastrophic reactions", characterized by anxiety and crying during stressful situations (Gainotti, 1972; Hecaen, 1969; Starkstein, Fedoroff, Price, Leiguarda, & Robinson, 1993). On the other hand, patients with right-hemisphere damage were described as jocular, apathetic and indifferent (Denny-Brown, Meyer, & Hornstein, 1952; Gainotti, 1972; Hecaen, 1969)

Despite these observations, little is known about emotional experience in patients with unilateral lesions. It is unclear if the alterations in emotional experience described are the result of a primary deficit in the ability to comprehend and/or express an emotion, or of an abnormal

experiential response (Ruckdeschel-Hibbard, Gordon & Diller, 1986). A study which directly examines hedonic experience (i.e., experience of pleasantness and unpleasantness) may help to clarify this issue.

The nature of the lateralized differences is also unclear. In studying emotion, researchers have focused on the role of emotional valence, as well as cognition (e.g., Davidson, 1984; Heller, 1990; Tucker, 1981; Tucker & Williamson, 1984). As subjects with brain lesions often have deficits in cognition, the emotional deficits observed in such subjects may be more directly related to difficulties in the subject's ability to cognitively process the stimuli used to elicit emotion. One may wonder if the hemispheric asymmetry in emotional experience and expression is related to hedonic tone, or if it is more cognitive in nature, and related to the way in which information is processed by the two hemispheres (see Ehrlichman & Bastone, 1992a).

This dissertation will examine hedonic experience by using odorants to elicit hedonic (i.e., pleasant versus unpleasant) experience and facial expression in patients with unilateral vascular brain lesions. A number of researchers have indicated that odorants can evoke emotional responses and that perception of their hedonic aspects require less cognitive and linguistic mediation than other types of stimuli, such as voice intonation or facial expression (Steiner, 1979; Ehrlichman and Bastone, 1992b; Engen, 1982; Izard, 1993). Indeed, hedonic valence is perhaps the most salient psychological attribute of an odor (Engen, 1982; Schiffman, 1974; Tassinary, 1985).

REVIEW OF THE LITERATURE

Emotional Processing in Normal Subjects

Perception of Emotion via Prosodic and Facial Expression. In order to examine lateralized differences in the appreciation of emotion in normal subjects, dichotic listening and tachistoscopic procedures have been used. Such procedures can examine right- versus left-hemisphere contributions in processing emotional material. By determining ear or visual field advantages via recognition accuracy or reaction times, hemispheric dominance in emotional perception can be inferred.

Prosody. For appreciation of emotional prosody, the majority of studies have found a left ear (right hemisphere) advantage for detecting affective tone in speech (Bryden & MacRae, 1988; Haggard & Parkinson, 1971; Safer & Leventhal, 1977), in nonverbal communication such as crying and laughing (Carmon & Nachson, 1973; King & Kimura, 1972), and in musical passages (Bryden, Ley & Sugarman, 1982). For most, emotional valence did not play a role in hemispheric asymmetries, although the Carmon and Nachson (1973) study indicated there was a greater right-hemisphere advantage in detecting the emotional content of negatively-toned (i.e., crying) stimuli.

Faces and Other Visual Stimuli. Studies of perception of emotional facial expression use several methodological approaches, including recognition of same versus different emotion, detection of emotional versus non-emotional faces, and judging the degree and direction of emotionality. The outcome of such studies appears to depend upon the methodological approach used to examine hemispheric asymmetries in perception of emotional facial expression (see Ley & Strauss, 1986). Almost all studies examining the recognition of same

versus different emotions support a left visual field (LVF) (right hemisphere) advantage across all types of stimuli (e.g., schematic drawings, photographs) of emotional facial expression (for review, see Borod, Koff, & Caron, 1983; Bryden & Ley, 1983; Ley & Strauss, 1986). Most of these studies required subjects to match the presented expression to an exemplar and used short exposure durations (approximately 80 msec). Other factors appear to modulate the LVF superiority, including gender, with some studies report a greater LVF advantage for men (Safer, 1981), whereas others report this effect for women (McKeever & Dixon, 1981).

For free-field viewing, a left-perceiver bias (e.g., right-hemisphere advantage) in emotional facial perception has been demonstrated across several studies using photographs and videotaped clips (Borod, St. Clair, Koff, & Alpert, 1990: Borod, Vingiano, & Cytryn, 1989; Jaeger, Borod & Peselow, 1987; Levine & Levy, 1986; Levy, Heller, Banich & Burton, 1983; Moreno, Borod, Welkowitz & Alpert, 1990; Sackeim & Grega, 1987). For the photographic stimuli, a chimeric face is created by using two left or two right hemifaces, or by an emoting hemiface and a neutral hemiface presented in original or mirror-reversed orientation. Videotaped clips are simply presented to the raters either in original or mirror-reversed orientation. This bias is apparent regardless of the neurological status of the poser, as seen in posers with right and left unilateral lesions and in normal adult subjects.

Despite many studies suggesting right hemisphere dominance in the appreciation of affective facial expression, some investigations support the valence hypothesis. As previously suggested, differences between these studies and those supporting the right hemisphere hypothesis appear to be related to the methodology used.

Dimond and his colleagues (Dimond & Farrington, 1977; Dimond, Farrington &

Johnson, 1976) examined subjects' subjective ratings and heart rate responses to pleasant, unpleasant or affectively neutral film clips (i.e., a humorous cartoon, a surgical operation, and a travel film) while wearing contact lenses which restricted vision to either the left or right hemisphere. The films were rated as being more unpleasant and horrifying when presented to the right hemisphere. The cartoon clip elicited greater heart rate changes when presented to the left hemisphere, whereas the heart rate change for the surgical film was greater when presented to the right hemisphere. These findings suggested that the two hemispheres have different hedonic propensities, where the right hemisphere is more negatively-toned.

Valence effects have also been found in studies requiring subjects to determine emotional from non-emotional faces. Reuter-Lorenz and her collaborators (Reuter-Lorenz & Davidson, 1981; Reuter-Lorenz, Givis & Moscovitch, 1983) presented pairs of photographed faces from the same individual (one neutral, one emotional) to their subjects. Subjects were asked to identify the side (right versus left visual field) in which an emotional expression appeared. Subjects were more accurate for RVF than LVF presentations. Yet, they also found that reaction times were faster to RVF presentations for happy faces and LVF presentations for sad faces. In one study (Reuter-Lorenz & Davidson, 1981), exposure time to the stimuli was approximately three times longer than those used in other studies demonstrating a right hemisphere advantage. Why and how length of exposure time produces this effect is unclear.

Likewise, several other studies have found valence effects when subjects were required to judge the degree of emotionality. Some have found intensity differences as a function of hemispheric input, where happy faces were judged more positively when presented to the left hemisphere (RVF) (Davidson, Mednick, Moss, Saron & Schaffer, 1987; Natale, Gur & Gur,

1983). More recently, valence effects have been demonstrated in a study using neuroimaging techniques to examine regional cortical activity, via cerebral blood flow (CBF) (Gur, Skolnick, & Gur, 1994). Here, tasks requiring the discrimination of facial emotion (happy from neutral, sad from neutral) and non-emotional tasks (age discrimination) were used. After viewing each stimulus for 7 seconds, subjects were asked to rate the intensity of the facial expressions on an intensity scale, ranging from very happy to very sad. Results indicated that for the emotional tasks, there was greater right parietal activation in comparison to the non-emotional task. These investigators also reported an interaction between task and region activated, with greater left frontal activation for the happy discrimination task relative to the sad discrimination task. When task performance was correlated to regional CBF differences, performance on the sad discrimination task correlated to right parietal activation, whereas performance on the happy discrimination task correlated with left frontal activation.

It is not clear why differences in task demands may produce differential effects in terms of the emotional valence of the stimuli. Some have proposed that differences may arise in certain studies where cognitive demands have been minimized (Reuter-Lorenz et al., 1983), whereas others argue that differences may be related to functional demands of the task (e.g. if tasks requires holistic versus analytical judgments) (Borod et al., 1983). In any event, the majority of studies suggest a right hemisphere superiority in the perception of emotional facial expression.

Emotional Facial Expression. One of the earliest investigators to note the functional importance of facial expressions was Charles Darwin (1890), who made detailed observations that different types of facial expressions were associated with specific emotions. Thus, many

researchers have used facial expressions to study emotion, as it is an observable indicator of emotional experience. For those interested in learning about hemispheric contributions in emotion, the focus has been on facial asymmetries in expression. As the lower part of the face is innervated by the contralateral hemisphere, inferences can be made about hemispheric dominance.

A number of studies have examined asymmetries in both spontaneous and prompted facial expressions (for review, see Borod, 1993; Borod & Koff, 1984; Borod, Haywood, & Koff, 1997). Spontaneous expressions are defined as those movements which arise from an evocative emotional situation and are unintended; prompted expressions are those which are requested of the subject and are clearly intended (Borod & Koff, 1984). The emotional expressions elicited are judged by naive raters to examine the presence of a facial response, its accuracy, its intensity, and extent of facial asymmetry. Facial expressions have also been examined via facial action coding procedures, such as the Facial Action Coding System (FACS) developed by Ekman and Friesen (1978), where activation of specific facial muscles is noted.

Neuroanatomical Considerations in Facial Expression. In order to appreciate the nature of hemispheric involvement in emotional expression, the neuroanatomical substrates and pathways underlying this behavior are reviewed. The facial musculature is innervated by the seventh cranial nerve (the facial nerve). Different upper motor pathways are used for voluntary and for emotionally induced movements, and thus method of elicitation is important to consider. Indeed, neurologists have noted the extent of facial paralysis in both spontaneous and voluntary expressions in their examinations to aid in determination of lesion site (Monrad-

Krohn, 1924). The neuroanatomical substrates and pathways for each type of expression will be considered separately.

Voluntary expressions involve the pyramidal system, with signals for these expressions arising from the precentral gyrus in area 4 of the motor cortex. The corticobulbar fibers descend through the corona radiata to the internal capsule and project to the motor nucleus of the facial nerve (Van Gelder & Van Gelder, 1990). The cortical information is projected to the nucleus either directly or indirectly (i.e., via interneurons in the brainstem reticular formation). Thus, direct cortical projections to the facial musculature are contralateral in origin, whereas indirect cortical projections receive input from subcortical motor areas and are more likely bilateral (Holstege, Kuypers & Dekker, 1977). The projections from the facial motor nucleus are topographically arranged. Fibers from the ventral part of the nucleus project bilaterally, innervating muscles in the upper face (e.g., forehead and upper eyelid), whereas fibers from the dorsal part of the nucleus are predominantly contralateral, innervating the lower face (e.g., nose, lips, cheeks) (Borod & Koff, 1984; Wilson-Pauwels, Akesson & Stewart, 1988).

The pathways for spontaneous expressions are thought to involve the extrapyramidal system. Van Gelder & Van Gelder (1990) note that this system coordinates oral and facial activities in response to gustatory and olfactory stimulation. The pathways for spontaneous expressions are complex, multisynaptic, and not as well understood as those for deliberate expressions (Diamond & Frew, 1979). The brain regions implicated in spontaneous expressions are widely distributed (Borod & Koff, 1984), and include the frontotemporal cortex, limbic system, putamen, globus pallidus, anterior ventral thalamus, subthalamus, hypothalamus, midbrain and pons (Myers, 1976; Van Gelder & Van Gelder, 1990). It is not

clear if the pathways are ipsilateral, contralateral or bilateral and how they innervate the upper and lower parts of the face (Borod & Koff, 1984; Van Gelder & Van Gelder, 1990).

Studies of Spontaneous and Posed Expression. Several reviews have been written on facial asymmetries during emotional expression, and the following section summarizes some of these findings (Borod & Koff, 1984; Borod, Haywood, & Koff, 1997; Campbell, 1986; Skinner & Mullen, 1991). These investigators have evaluated numerous studies of both posed and spontaneous expressions to determine side and extent of hemiface asymmetry. Findings related to asymmetry in emotional expression will be reviewed, as well as their possible relationship to other factors (e.g., handedness or facial movements unrelated to speech or emotion).

In addition, Borod and her colleagues (1997) have also examined the role of social display rules (i.e., whether or not the camera or observer was concealed when expressions were elicited) for spontaneous facial expression, as some investigators have suggested that when a poser is being observed, asymmetries are more likely to occur (Ekman, Hager & Friesen, 1981). In instances when social display rules are maximized (i.e., another person is present during the experiment or the camera is not concealed), expressions may be more deliberate, whereas when such rules are minimized, these expressions may be more spontaneous and reflective of underlying experience. Most studies examining display rules have not been used to address lateralization of affective processes, but rather social contexts in producing certain affective behaviors, such as particular types of smiles. For instance, activation of facial musculature is differentially involved for "felt" smiles (e.g., zygomatic major and obicularis oculi, pars lateralis) versus "deliberate" smiles (e.g. zygomatic major alone)

(discussed in Ekman & Davidson, 1993; Ekman, 1984).

Several of the reviews (Borod & Koff, 1984; Borod et al., 1997; Skinner & Mullen, 1990) have determined direction of facial asymmetry (e.g., left, right, equal) as a function of emotionality. Overall, it was found that the left side of the face was judged as more intense or expressive than the right side of the face for emotional versus neutral expressions. In their meta-analysis of several studies, Skinner & Mullen (1990) reported this effect was weak-to-moderate in magnitude. Borod and her colleagues (1997) reported that this type of asymmetry was found more frequently for negative than for positive emotions; asymmetries in positive emotional expressions were more frequently equal or right-sided, especially for those which were spontaneously produced. This difference in terms of valence suggests greater right hemisphere involvement in negative emotional expression, with some degree of left hemisphere involvement in positive emotional expressions.

When evaluating methods of eliciting expressions (i.e., spontaneous versus posed), Borod and her colleagues (1997) examined the studies to determine if posed expressions were more asymmetrical than spontaneous expressions. For the 49 studies examined, nonparametric tests examining the distribution of facial asymmetries revealed no significant differences in asymmetry between the two types of expressions. Finally, display rules had no effect on the direction or presence of facial asymmetries in spontaneous facial expressions. Overall, their findings indicate expressions were more intense or expressive for the left than the right hemiface, regardless of elicitation condition.

Investigators have also examined the role of other factors in facial expression, such as handedness, gender and non-emotional facial movement, to aid in interpretation of the above

findings. Several studies indicate that facial expressions tend to be left-sided regardless of handedness and gender (Borod, et al., 1996), yet these factors do appear to mediate the degree of asymmetry observed (for review, see Borod & Koff, 1989; Campbell, 1986). In terms of peripheral factors, studies by Borod and her colleagues examining size and mobility of right versus left hemiface have found no relationship between these factors and facial asymmetry (Borod, Koff, Lorch, & Nicholas, 1986). Lastly, non-emotional facial movements are more likely to involve the left- rather than right-side of the face (Borod & Koff, 1983). Thus, the left-sided asymmetry observed in facial action appears to involve facial movements in general, both emotional and non-emotional, and that certain factors, such as gender and handedness, modulate the degree of this asymmetry.

Hemispheric Asymmetry and Emotional Experience. In order to examine regional brain activity underlying emotion in healthy subjects, most studies have used measures of dynamic brain activity. Davidson & his colleagues have conducted numerous investigations using electroencephalography (EEG) to investigate regional brain activation in their studies of emotion (Davidson & Tomarken, 1989). For these studies, a specific type of spectral frequency analysis is used, to examine the power density in the alpha band. Alpha waves are defined as activity between 8 and 13 Hz, and alpha is thought to be an index of relative arousal. According to Davidson (1984), a review by Shagass (1972) indicates that alpha power is inversely related to activation (desynchrony of alpha). More recently, studies have examined regional activity using functional neuroimaging techniques, such as positron emission tomography (PET). One shortcoming of these newer methods is that maintenance of positive affect is difficult, as some procedures, like PET, are restrictive and mildly invasive (Davidson,

1992).

Based on the EEG methodology, research by Davidson and his colleagues suggest hemispheric differences in positive and negative emotional experience (Davidson, 1984a, 1984b; Davidson & Tomarken, 1989; Fox, 1991). In order to verify the presence of the intended emotion, the EEG epochs examined are those which coincide with some type of expressive behavior, such as a facial expression or gestural response (e.g., an infant reaching up to his/her parent). The hemispheric activation differences have been found only in the frontal and anterior temporal regions, whereas differences in parietal asymmetries are unrelated to measures of affective responding. Furthermore, individual differences in frontal EEG asymmetry are related to reports of trait measures of positive and negative affect (Tomarken, Davidson, Wheeler & Doss, 1992). Here, subjects with extreme left frontal asymmetries at rest report greater positive then negative dispositional mood, whereas individuals with the opposite pattern of frontal asymmetry report greater negative mood.

These findings suggest that anterior brain regions are related to emotional experience and expression. In terms of these affective differences, Davidson and his colleagues argue that the anterior asymmetries observed are more related to the dimension of approach and withdrawal, with the right anterior region subserving the withdrawal system, and the left anterior region subserving an approach system. One of their studies examined this theory indirectly by eliciting emotions (i.e., happiness, disgust) which are ladened with these action tendencies (Davidson et al., 1990). Similar to findings in other studies, disgust responses were associated with right-sided activation in the frontal and anterior temporal regions, whereas happiness was accompanied by left-sided activation in the anterior temporal area.

One drawback of using EEG to examine regional cerebral activation is that it has limited spatial resolution. In addition, the electrical activity recorded from the scalp and analyzed by different frequency bands is generated in the cortex and does not necessarily reflect subcortical activity (Davidson & Tomarken, 1989). Therefore, more recent studies have used PET to examine functional activity in both cortical and subcortical regions (George et al., 1995; Pardo, Pardo, & Raichle, 1993; Partiot, Grafman, Sadato, Wachs & Hallet, 1995). These functional neuroimaging studies have allowed researchers to examine the underlying neuroanatomical substrates involved during different emotional states using a variety of mood induction techniques.

Findings from functional imaging studies are not as clear-cut as those using EEG, and systematic lateralized changes in activity have not emerged. In fact, such studies suggest that happy and sad states are mediated bilaterally. In one study limited to examining regional cerebral blood flow (CBF) in outer layers of the cortex, no interhemispheric differences were found between happy and sad states (Schneider, Gur, Jaggi & Gur, 1994). George et al. (1995) found an increase in regional cerebral blood flow activity during sadness in widespread limbic and paralimbic structures, including the right medial frontal gyrus, left dorsolateral prefrontal cortex, and bilaterally for the cingulate gyrus, caudate, putamen, thalamus, fornix and left insula. During happiness, decreased activity was observed in bilateral temporal-parietal and right frontal cortex. Pardo and colleagues (1993) found increased activity in the bilateral inferior and orbitofrontal cortex during dysphoric states. In a third study, lateral prefrontal regions (right superior frontal gyrus, bilateral middle frontal gyrus) and bilateral anterior temporal cortices were activated when subjects were asked to experience feelings and plan

activities during a grief state versus a non-emotional state (Partiot et al., 1995). Thus, the studies differ in the brain regions activated during transient sadness. These differences may be related to how the mood state was induced, for instance if it was internally-generated (i.e., recalling a sad event) versus externally-generated (i.e., looking at films or faces) (see George et al., 1995 for discussion). For example, one might expect different regions of activation if the induction technique is more perceptual in nature (perhaps activating posterior regions as well as more frontal and limbic regions with the occurrence of the mood state) versus recollection of a sad event (possibly activating more anterior corticolimbic circuits). In addition, although these techniques are advantageous over electrophysiological methods in demonstrating regional cerebral differences, temporal resolution is limited because of the long integration time required for acquisition of the emission signals. Thus, the timing of these activations in different brain regions is indistinct, and more work is needed to clarify the nature of these findings.

Summary of Findings for Normal Subjects. Although there are some exceptions, most studies of prosodic and facial emotional perception indicate a greater role for the right hemisphere in the appreciation of emotion. Only one study to date has examined regional activation during a discrimination task using emotional facial expressions (Gur et al., 1994), and it suggests a greater right parietal activation for emotional versus non-emotional tasks. Similarly, for facial expression, the left side of the face (i.e., right hemisphere) is more expressive than the right hemiface for emotional than for neutral expressions, although the effect appears to be a modest one. When valence has been shown to produce differential hemispheric involvement during perceptual and expressive emotional tasks, the effect is usually either for a greater role of the right hemisphere for negatively-valenced stimuli/expressions, or

for a reduced role of the right hemisphere for positively-valenced stimuli/expressions.

The greatest differences seen regarding left versus right hemispheric activation are in those studies examining emotional experience. Both EEG and functional neuroimaging studies indicate that anterior brain regions (i.e., frontal and anterior temporal) are most involved in emotional experiential states. Although the lateralized findings suggested by the EEG studies have not been replicated in the functional neuroimaging techniques, EEG studies suggest the left hemisphere is involved in positive, approach-related experience/expression, whereas the right hemisphere is involved in negative, withdrawal-related experience/expression. Overall, these findings confirm the importance of using a componential (e.g., Borod, 1993) approach to examine the role of hemispheric asymmetries in the generation of emotional behaviors (Davidson, 1993).

Emotional Processing in Patients with Focal Brain Lesions

In order to clarify hemispheric contributions to emotional processing, emotional behavior in patients with unilateral brain lesions resulting from pathological etiologies (e.g., CVA, tumor) have been examined. This section will review research using such patients. In these studies, comparisons are made between subjects with left hemisphere damage (LHD), right hemisphere damage (RHD) and normal controls (NC).

Perception of Prosodic and Facial Emotional Expression. Appreciation of emotional stimuli has been examined in patients with brain lesions by noting the accuracy of performance on discrimination and identification tasks. Findings for each type of stimuli (i.e., prosodic, facial) will be examined separately, as results for prosody are more variable than those for facial

expression.

Prosody. For perception of emotional prosodic expression, some studies have found that the RHDs were significantly impaired relative to LHDs and NCs on discrimination and/or identification (Bowers, Coslett, Bauer, Speedie, & Heilman, 1987; Denes, Caldognetto, Semenza, Vagges, & Zettin, 1984; Heilman, Bowers, Speedie & Coslett, 1984; Heilman, Scholes, & Watson, 1975; Tucker, Watson & Heilman, 1977). Such studies suggest that patients with right posterior regions (i.e., temporal parietal areas) have the greatest deficits (Heilman et al, 1975; Tucker, et al., 1977; Starkstein, Federoff, Price, Leiguarda, & Robinson, 1994). One difficulty in interpreting such findings is whether an appropriate number of individuals with left posterior lesions are included, as such patients are often excluded due to language comprehension deficits. Other evidence suggests that subcortical lesion site (e.g., basal ganglia) may also play a role in perception of prosodic stimuli (Cancelliere & Kertesz, 1990; Starkstein et al., 1994). When valence was considered, no hemispheric differences were found (Heilman, et al., 1984; Starkstein et al., 1994).

Others have found no difference between RHDs and LHDs on identification tasks, although both groups were impaired relative to NCs (Cancelliere & Kertesz, 1990; Denes et al., 1984; Tompkins & Flowers, 1985; Van Lanker & Sidtis, 1992). It appears that the lack of group differences between the two patient groups may be related to task difficulty and/or to the cognitive demands required. For instance, Tompkins and Flowers (1985) reported that a more demanding task (i.e., one having four response choices) required processing by both hemispheres, and thus both LHD and RHD groups perform poorly, whereas only RHDs demonstrated impairments on a simpler task of identification (i.e., one having two response

choices). Other investigators argue that differences observed between groups are unrelated to emotion, and instead are due to other factors, such as differential auditory functions of the right versus left hemisphere for certain acoustic parameters (i.e., pitch and duration) (Van Lanker & Sidtis, 1992) or right hemisphere contributions in attention and resistance to distraction (Bowers et al., 1987; LaLande, Braun, Charlebois, & Whitaker, 1992).

Faces. In terms of perception of emotional facial expression, the majority of studies indicate greater deficits associated with right hemisphere damage on discrimination and/or identification tasks (Borod, Koff, Perlman-Lorch & Nicholas, 1986; Bowers, Bauer, Coslett & Heilman, 1985; Cicone, Wapner & Gardner, 1980; DeKosky, Heilman, Bowers & Valenstein, 1980; Etcoff, 1984; see also, Ahern et al., 1991). One methodological concern in such studies is whether this deficit is associated with general difficulties in recognizing facial and visuospatial stimuli. Therefore, several studies have included measures of facial recognition and visuospatial perception, in order to control for general processing difficulties. In most cases, a deficit remained in processing emotional facial expression in the RHD group (Borod, Martin, Alpert, Brozgold & Welkowitz, 1993; Bowers et al., 1985; Cicone et al., 1980; Etcoff, 1984), except in one study (DeKosky et al., 1980). In the latter case, review of the subjects' data indicated that several subjects performed within normal limits on the control tasks, but were impaired on affective facial perception tasks (Heilman & Bowers, 1990). Thus, it appears that deficits in perception of emotional facial expressions are not purely the result of an underlying visuoperceptual impairment or a general facial recognition deficit. In the few studies examining intrahemispheric effects, no differences were found between anterior and posterior lesions (Braun, Denault, Cohen, & Rouleau, 1994; Bowers, et al., 1985). However, Etcoff (1984)

reported a dissociation between recognition of identity and of emotion in several RHD subjects, who differed in terms of site of lesion within posterior brain regions. This finding is supported by research in non-human primates suggesting separate populations of neurons in posterior regions which preferentially respond to facial expression and facial identity (for discussion, see Bowers, Bauer & Heilman, 1993).

In terms of valence effects for perception of facial emotion, Borod et al. (1986) found that relative to LHDs, RHDs were impaired for negative, but not for positive, emotions. However, others have not found this effect (Bowers, et al., 1985).

Emotional Facial Expression. As in the review of studies using normal subjects, studies of posed and spontaneous emotional facial expressions will be examined separately. Borod (1993) has recently completed an extensive review of studies examining facial emotional expression in patients with unilateral brain damage. Overall, there was considerable variability in the findings between investigations for both posed and spontaneous facial expressions, where some studies found specific deficits in the RHD group, others found deficits in both RHDs and LHDs, while still others found no group differences. This variability appears to be due to methodological differences between studies, such as etiology of the hemispheric damage and procedures in quantifying expressions (for review, see Borod, 1993).

For posed facial expressions, some have found that RHDs were significantly less accurate or expressive than LHDs (Borod et al., 1986; Bruyer, 1981). Consistent with these findings, Weddell, Miller, & Trevarthen (1990) reported a trend for impoverished performance in the RHD group relative to LHDs and NCs. Others report that both RHDs and LHDs or just RHDs perform more poorly relative to NCs on certain measures of facial expression (Borod, et

al., 1990; Kent, Borod, Koff, Welkowitz, & Alpert, 1988; Kolb & Taylor, 1990). Yet, some studies have failed to find any difference between RHD, LHD and NC groups (Caltagirone et al., 1989; Heilman, Watson & Bowers, 1983; Weddell, Miller, & Trevarthen, 1990). Similarly, when intensity of facial expression was examined, no group differences were reported (Borod, et al., 1990; Caltagirone et al., 1989; Kent, et al., 1988). In terms of the anterior-posterior axis, some studies report that patients with anterior lesions are less able to pose facial expressions than those with posterior lesions (Kolb & Taylor, 1990; Weddell, et al., 1990).

Findings regarding interaction effects between emotional valence and side of lesion are also inconsistent for facial expressions. Borod and her colleagues have found that RHDs perform more poorly than LHDs and/or NCs, when posing positive emotional expressions (Borod, et al., 1986; Borod, et al., 1990; Kent, et al., 1988). For negative emotional expression, one study noted that RHDs were less expressive than LHDs (Bruyer, 1981), and another indicated that expressions for LHDs were less appropriate than RHDs and NCs (Caltagirone, et al., 1989). However, others report no group differences in terms of emotional valence (Weddell et al., 1990).

For spontaneous facial expressions, the majority have found impairments in RHDs relative to LHDs and/or NCs in terms of accuracy, responsivity, expressivity, intensity, and/or number of action units (a measure used for the FACS) (Blonder, Burns, Bowers, Moore, & Heilman, 1993; Buck & Duffy, 1980; Borod, Koff, Lorch & Nicholas, 1985, 1986; Borod et al., 1988; Martin, et al., 1990). In a study by Weddell, Trevarthen, & Miller (1988), both RHDs and LHDs produced fewer action units than control subjects. Several studies failed to find difference on any of these measures between RHDs, LHDs and/or NCs (Kolb & Milner,

1981; Mammucari et al., 1988).

Etiology of the brain insult is an important factor to consider, as Borod (1993b) noted that all studies reporting only global differences between those with cerebral vascular damage and NCs, and not between RHDs and LHDs, involved patients with tumors or surgical ablations. In light of this, she indicates that in studies using patients with tumors, those with anterior lesions were less frequently expressive (Kolb & Milner, 1981; Weddell et al., 1988) and were less accurate when expressing positive emotions (Mammucari et al., 1988; Weddell et al., 1988) than subjects with posterior lesions. For studies using patients with vascular lesions, RHDs with both anterior and posterior lesions were less accurate in producing facial expressions (Borod et al., 1986; Borod et al., 1988).

When effects of emotional valence were examined for measures of spontaneous facial expression, the findings were equivocal. For positive emotional expressions, RHDs' expressions were rated as less intense when compared to controls (Martin, et al., 1990), and were less expressive than LHDs and NCs (Blonder, et al., 1993); in addition, RHDs made fewer "positive" responses (i.e., smiles) after making incorrect responses on a card sorting task when compared to controls (Weddell et al., 1988). For negative emotional expressions, both RHDs and LHDs were less responsive than NCs (Mammucari et al., 1988), whereas other studies have noted relative impairments in RHDs in comparison to LHDs, including a decrease in responses to wrong sorts (Weddell, et al., 1988) and less frequent gaze aversion (Mammucari et al., 1988).

The above studies address deficits in expressive behavior (i.e., reductions in performance) following brain insult. However, excessive forms of emotional expression can

also occur in patients with neurological disorders in the form of pathological laughing and crying, e.g., pseudobulbar palsy (for review, see Shaibani, Sabbagh & Doody, 1994). In such patients, the emotional expression is discordant with experiential state. These responses are usually sudden, brief, stereotypical and occur in response to nonspecific or inappropriate stimuli. Unilateral or bilateral lesions disrupting the descending corticobulbar tracts can cause pseudobulbar palsy, and there is no single cortical lesion responsible for this condition (Heilman, Bowers & Valenstein, 1985; Shaibani, et al., 1994). In order to examine hemispheric asymmetries in emotion, Sackeim et al. (1982) retrospectively examined 119 cases of patients presenting with this disorder to determine the side of lesion. When the distributions were examined, they found that left-sided lesions were more often associated with crying and right-sided lesions associated with laughing, which is consistent with the valence hypothesis.

Pathological laughing and crying have been described in a small proportion of patients with epilepsy. Such expressive reactions occur during the ictal period of a seizure episode, and are known as gelastic (laughing) or dacrystic (crying) seizures. The mechanisms producing this condition are unknown. An opposite trend to the findings reported above has been observed in terms of hemispheric site of seizure focus and the type of seizure (Sackeim et al., 1982; Luciano, Devinsky & Perrine, 1993). In the same study previously reported, but with a different patient sample, Sackeim et al. (1982) found that gelastic seizures were twice as likely to be predominantly left- versus right-sided. Fewer cases of dacrystic seizures were reported (n=6), and these investigators found four which were right-sided, one which was left-sided and one in which the focus could not be determined. More recently, another study describing patients with dacrystic seizures reported that the seizure focus occurred in the non-dominant

temporal region in five out of seven patients, in the non-dominant frontal region in one patient, and in the frontocentral region for the last case (Luciano et al., 1993). Together, these findings suggest that dacrystic seizures are perhaps more likely to have their focus in the non-dominant hemisphere. Sackeim et al. (1982) argue that the seizures act to stimulate the emotional propensities of the left or right hemispheres, in support of the valence hypothesis (i.e., left-positive, right-negative) (cf Strauss, Wada, & Kosaka, 1983). However, Tucker (Tucker, 1981; Tucker & Frederick, 1989) offers an alternative explanation, arguing that seizures involving cortical and subcortical structures can disrupt corticobulbar pathways, and disinhibit underlying brainstem mechanisms involved in the emotional response.

Emotional and Mood Disturbances. Most formal studies of experiential states in such patients have focused on mood disturbances, rather than emotional states. The criteria in distinguishing emotion from mood differ between investigators (for discussion, see Davidson & Ekman, 1994). Thus, some argue emotions are of shorter duration, are associated with unique facial expressions, and influence actions. On the other hand, moods are longer in duration and affect cognitions. Relatively few studies address changes in emotional responses following brain insult, but most focus on mood, primarily depressed mood states.

Hemispheric differences in emotional responses and states were first described by Goldstein (1939), who noted the occurrence of catastrophic reactions after brain-damage. He characterized such a reaction as an anxiety response secondary to a decrease in coping skills. Gainotti (1972) and Hecaen (1962) were among the first to report that these reactions occurred more frequently after left-brain damage. Others, such as Denny-Brown et al. (1952), noted that subjects with right brain-damage were abnormally indifferent and apathetic. Citing

one of his earlier studies (Gainotti, 1969), Gainotti (1989) observed that the indifference reactions were often accompanied by an inappropriate tendency to joke.

In an early study examining emotional behaviors after unilateral lesions, Gainotti (1972) noted three patterns of emotional behavior: (1) catastrophic reactions characterized by tears, swearing, renouncement, compensatory boasting, and refusals; (2) anxious-depressed mood characterized by discouragement, tendency to boast about past abilities, statements and expectations of incapacity, and excuses; and (3) either indifference reactions characterized by anosagnosia (or minimization of disability) or tendency to joke in euphoric manner. No rationale is provided as to why these symptoms are characteristic of the three patterns of reactions. Nevertheless, in terms of occurrence of these behaviors, he found that catastrophic or anxious-depressive reactions were more frequently found in patients with left hemisphere lesions, whereas indifference/euphoric reactions were found in patients with right hemisphere lesions. Gainotti reasoned that the catastrophic reaction was an appropriate response to disability, whereas the indifference reaction was inappropriate. Thus, he hypothesized that the non-dominant hemisphere was crucially involved in affective behaviors. An alternative explanation focusing on the depressed and euphoric aspects after brain injury is that the left hemisphere is involved in positive emotional experience/expression, whereas the right hemisphere is involved in negative emotional experience/expression; abnormal responses in patients with unilateral lesions are the result of contralateral disinhibition.

Since Gainotti's (1972) study, few have directly examined emotionalism and catastrophic reactions (CR). One problem is in defining catastrophic reactions in a reliable and valid manner. Starkstein and his colleagues examined the presence of such reactions in a

population of consecutive hospital admissions using a scale based on Goldstein's and Gainotti's descriptions of CR (Starkstein, Fedoroff, Price, Leiguarda, & Robinson, 1993). Observations were made by a neurologist after conducting a neurological and brief neuropsychological examination. Of 62 admissions, 12% demonstrated CR, and CR was more frequent in those with a personal or family history of psychiatric disorders. Unlike Gainotti's study, patients with and without CR had similar frequencies of right versus left lesions, but those with CR most frequently had lesions involving the basal ganglia. Lastly, patients with CR had post-stroke depression and anxiety and were more likely to have family and/or personal history of depression. The authors speculate that CR is not a unique clinical syndrome, but is merely a behavioral expression in patients with post-stroke depression, suggesting that CR may only be a variant of depression.

Emotionalism after ischemic lesions was also examined in patients interviewed at 3 time points (1, 6 and 12 months) after stroke onset (House, Dennis, Molyneux, Warlow, & Hawton, 1989). Incidence of emotionalism increased at 6 month follow-up, decreasing by the 12 month follow-up. Individuals identified as having greater emotionalism also had higher scores on measures of mood disorder (i.e., they were more depressed). Episodes of emotionality were identified by patients in their self-report to several questions. These investigators found that patients with left anterior hemisphere lesions tended to report greater incidences of tearfulness with sudden episodes of crying. It is difficult to compare this study to that of Starkstein et al. (1993) for a number of reasons, including the measures used to assess tearful episodes, and in the authors' operational definitions of emotionalism and catastrophic reactions.

A number of studies have examined depressed states following focal brain lesions.

Studies examining depressed mood have used a variety of measures, the most common being the Beck Depression Inventory, Hamilton Inventory for Depression, Zung Depression Scale, Minnesota Multiphasic Personality Inventory, and Present Status Examination (PSE). Some investigators, such as Starkstein and his colleagues (see Starkstein & Robinson, 1989), used symptoms from the PSE to determine if patients met criteria for major or minor depression using the Diagnostic and Statistical Manual - III (DSM-III). Extent and presence of depression have been examined as a function of site of hemispheric damage and time since onset of the brain insult.

Robinson and his colleagues have found a higher incidence of depression in patients with left-hemisphere lesions (Robinson & Price, 1982; Robinson, Kubos, Starr, Rao & Price, 1984; Robinson, Starr, Kubos & Price, 1983; Starkstein, Robinson, Berthier & Price, 1988). At the time of acute hospitalization, for LHDs, severity of depression was significantly correlated with proximity of the lesion to the frontal pole, and major depression was most prevalent in those with anterior left-hemisphere lesions (Robinson et al., 1984). This relationship is observed regardless of handedness (Robinson, Lipsey, Bolla-Wilson, Bolduc & Pearlson, 1985). For those with right-hemisphere lesions, lesions farthest from the frontal pole were associated with the most severe depressions. The occurrence and severity of depression does not appear to be related to functional or cognitive impairments. On follow-up studies, those with major depression spontaneously remit one to two years post-stroke, whereas patients with minor depression (dysthymia) remain depressed two years later (Robinson, Bolduc & Price, 1987; Robinson, Starr & Price, 1984).

In later studies, the role of subcortical lesions, particularly in basal ganglia regions, was

examined (Starkstein, Robinson & Price, 1987; Starkstein, Robinson, Berthier, Parikh & Price, 1988). Consistent with earlier findings, there was a greater incidence of depression with left anterior lesions. In addition, at the time of acute hospitalization, patients with left basal ganglia lesions, primarily those involving the head of the caudate nucleus, had a higher frequency of depression than those with right basal ganglia lesions.

Although some investigators have replicated the findings of a higher prevalence of depression in patients with left-hemisphere lesions (De Bonis, Dellatolas, & Rondot, 1985; Gasparrini, Satz, Heilman, & Coolidge, 1978), others have not found this effect (Dikmen & Reitan, 1974; Ebrahim, Barer & Nouri, 1987; Folstein, Maigerger, & McHugh, 1977; Gass & Russell, 1986; House, Dennis, Warlow, Hawton, & Molyneux, 1990; Irle, Peper, Wowra, & Kunze, 1994; Sinyor et al., 1986). The studies differed in a number of ways, including assessment measures, etiology of brain injury, and time tested post-injury.

For the two studies which most closely replicated the methodology used by Robinson and his colleagues, both failed to find evidence for lateralization of post-stroke depression (House et al., 1990; Sinyor et al., 1986; see also Starkstein & Robinson, 1994). Nevertheless, there are significant methodological differences between these two studies and those of Robinson's, including criteria in defining lesion location and hospitalization status at time of stroke. Yet, both of these studies did find a relationship between severity of depression and proximity of lesion to the frontal pole, albeit weaker than that reported by Robinson et al. (1984). While Sinyor et al. (1986) found this relationship only for the LHDs, for RHDs, severity of depression negatively correlated to the proximity of frontal pole. However, House et al. (1990) found a negative correlation between depression and proximity of lesion to the

frontal pole regardless of side of lesion. This latter effect has also been reported by other investigators (Lipsey, Robinson, Pearlson, Rao, & Price, 1983; Robinson et al., 1985; Starkstein et al., 1987; Eastwood, Rifat, Nobbs, & Ruderman, 1989; but see Black & Black, 1982).

Unlike the numerous studies examining depression following brain insult, fewer studies have examined manic states secondary to unilateral brain injury. In part, this is due to the fact that manic symptoms rarely occur following cerebral vascular accident (Starkstein, Pearlson, Boston, & Robinson, 1987). The symptoms of secondary mania are similar to mania of unknown neuropathology, including elated mood, pressured speech, flight of ideas, grandiosity, paranoid ideation/delusions and insomnia (Cummings & Mendez, 1984; Starkstein et al., 1987; Starkstein, Boston, & Robinson, 1988). Mania subsequent to cerebral vascular accident usually develops immediately after injury but has been reported to occur several years post injury (Starkstein et al., 1988). In addition, those developing mania more commonly have a family history of affective disorder, may develop bipolar disorder, and may have a history of post-stroke depression (Starkstein et al., 1987, 1988). Lesion location has also been examined in patients with a mixed etiology of brain insult, with reports of mania following damage to the right thalamus, temporobasal regions, orbitofrontal regions, caudate nucleus, and following pituitary adenoma resection (Cummings & Mendez, 1984; Starkstein et al., 1987, 1988). Starkstein and his colleagues report a higher frequency of right hemisphere lesions associated with mania, but when these patients were compared to a lesion control group, the manic patients had higher bifrontal and third ventricle brain ratios, suggesting bilateral frontal subcortical and diencephalic brain atrophy (Starkstein et al., 1987, 1988).

Several studies have examined emotional responses following hemispheric sedation and hemispherectomy. Unilateral carotid injection of sodium amytal is used to sedate one hemisphere to examine lateralization of language functions. In their reviews of the older sodium amytal studies, Sackeim (1991), Tucker (1981) and Tucker & Frederick (1989) report that several studies conducted in the 1960's found that sedation of the left hemisphere most frequently produced dysphoric states/expressions, whereas right-sided injections induced euphoric states/expressions, with other studies failing to confirm these results. In studies observing hemispheric differences in emotional reactions, the reactions only occurred in some patients (Sackeim, 1991). Likewise, a recent study by Lee, Loring & Meador (1990) also noted that lateralized emotional responses occurred in a subgroup (59% of their sample) of their patients. Criticisms of the sodium amytal studies include evidence suggesting that euphoric mood is associated with higher barbiturate doses (Silberman & Weingartner, 1986), and that emotional changes occur only after normalization of EEG activity in the sedated hemisphere (Sackeim, 1991). In terms of mood alterations following hemispherectomy, only one study has been conducted retrospectively (Sackeim et al., 1982), and these findings were equivocal.

Determining exactly how experiential and mood states are lateralized from such studies is difficult for a number of reasons. First, the results of certain studies, such as those conducted by Robinson, Starkstein and colleagues, are not consistently replicated by other investigators. Second, definitions of emotional behavior, such as catastrophic reactions, differ between studies, and thus are not comparable. Third, investigators focus on different aspects of the altered behavior, so that "the question now has become how to tell which hemisphere is

contributing to which affective state" (Tucker, 1981, p. 30). Regarding this last point, some investigators have concentrated on apparent differential valence effects which may occur following injury (i.e., mania/euphoria versus depression/dysphoria), whereas others focus on presence or absence of emotional/mood responses (i.e., indifference reactions versus catastrophic reactions/depression). Each of these interpretations then lead to different theories regarding hemispheric contributions to emotional behavior, namely, the valence hypothesis for those focusing on differential valence effects, and the right hemisphere hypothesis for those focusing on reductions in emotional responses following right hemisphere lesions.

Yet another unanswered question in this research concerns the underlying mechanisms producing such disturbances in emotional behavior. The affective dysregulation resulting from unilateral brain lesions can be explained either by contralateral or by ipsilateral disinhibition (Davidson, 1984a; Sackeim et al., 1982; Tucker, 1981; Tucker & Frederick, 1989). If affective dysfunctions are the result of contralateral disinhibition, then each hemisphere exerts reciprocal inhibitory or regulatory control over regions in the other hemisphere (Davidson, 1984a; Sackeim et al, 1982). Thus, if the valence model of emotional processing is operative, left hemisphere lesions will result in less control over right-hemisphere functions releasing activation of emotional tendencies of the right hemisphere, and enhancing the appearance of negatively-valenced expressions/experiences. Conversely, right hemisphere lesions will result in the emergence of positively-valenced expressions/experiences, due to disinhibition (i.e. release) of left-hemisphere propensities. Affective dysfunctions resulting from ipsilateral disinhibition suggests that unilateral lesions disinhibit or release ipsilateral subcortical regions from cortical control, resulting in the the occurrence of behaviors that are consistent with that

hemisphere's emotional tone (Tucker, 1981; Tucker & Frederick, 1989).

Summary of Findings in Patients with Unilateral Hemispheric Lesions. Studies investigating emotional processing in neurological populations are not as easy to interpret as those using healthy subjects. However, examination of affective behavior in those with hemispheric lesions may lead to a better understanding of the neural substrates involved in emotional behavior. Perception of facial emotion appears to rely on right hemisphere systems regardless of valence and appears to be separate from visuoperceptual (i.e., facial recognition) and visuospatial functions. Asymmetries observed in perception of prosodic emotion are more nebulous, as perception of prosody may be related to hemispheric differences in cognitive processing related to the demands of the task, such as in left versus right hemispheric differences in processing duration and pitch.

The findings regarding emotional facial expression depends upon the method by which expressions are elicited. For both posed and spontaneous expressions, findings are inconsistent, but most studies indicate greater deficits in patients with right-hemisphere lesions. For spontaneous expressions, greater deficits are observed in patients with anterior lesions than those with posterior lesions. Borod (1993) explains that inconsistencies among studies may be related to methodological variables, including etiology, demographic characteristics, procedures, and stimuli used to elicit expressions.

Of all the components of emotion studied, those examining emotional and mood disturbances following focal brain damage are the most perplexing. What has consistently emerged from such studies is that these disturbances are more likely to occur in patients with anterior lesions. Yet, the studies are highly variable regarding interhemispheric effects following

unilateral lesions. Deficits in emotional experience may in part be related to deficits in emotional perception and expression (Ruckdeschel-Hibbard et al., 1986). However, there are recent reports that certain emotional components are dissociable, where those with RHD and LHD experience emotion just as intensely as healthy controls, but those with hemispheric lesions can have deficits in the expression of emotion or in patterns of arousal (Borod, Rorie et al, 1996; Bowers, Bauer & Heilman, 1993; Cimino, Verfaellie, Bowers & Heilman, 1991; Gainotti, 1987; Meadows & Kaplan, 1994). As in studies of facial expression, methodological variables are likely important in studies of emotional experience and mood, and thus may account for the inconsistencies. Difficulties also appear to be related to different theoretical approaches in interpreting the findings, such as whether the investigators choose to focus on hemispheric differences related to valence or the apparent lack of an emotional response.

Use of Odors to Invoke Emotional Experience and Facial Expressions

Investigators of emotional processing have used a number of procedures to examine affective behaviors in the laboratory setting. This includes use of a number of means to induce emotional and mood states, such as viewing emotionally-ladened photographs or films, or imagery techniques. Many of these procedures were used in the studies reviewed in the previous sections. This next section reviews investigations using odors as a way to elicit affective experiences and responses.

Subjective Experience and Physiological Measures: Many claims have been advanced regarding the relationship between olfaction and emotion, as well the influence of odors on memory and cognition (Ehrlichman & Bastone, 1992a; 1992b; Jellinek, 1994; Richardson &

Zucco, 1989). Clearly, odorants are most salient to us in terms of their hedonic quality (i.e., pleasantness, unpleasantness). This is confirmed by psychophysical studies, where subjects are asked to judge the similarities between different odors; the most important dimension or factor to emerge is one of "affective properties" (Wright & Michels, 1964, p. 543) or hedonicity of odors (Engen, 1982; Schiffman, 1974; Tassinary, 1985). In normal subjects, ratings of the pleasantness of odorants are unrelated to performance on other olfactory tasks, such as detection, discrimination, identification and memory (Doty, Smith McKeown, & Raj, 1994).

It is unclear why this hedonic dimension is so prevalent in odors, but some suggestions are that there is a lack of linguistic terms and classification systems available to characterize odorants (Richardson & Zucco, 1989), that olfactory input utilizes similar anatomical substrates involved in emotion, including the amygdala and paleocortex (Van Toller, 1988), and that the hedonic experience itself is an integral part of olfactory (and taste) sensations (Schachtel, 1959, as cited in Ehrlichman & Bastone, 1992b). From an evolutionary perspective, olfactory hedonics evolved as signals important to the survival of the organism, such as good or bad food, and healthful or unhealthful environments (Ehrlichman & Bastone, 1992b). As to whether olfactory hedonic evaluations are innate or acquired has been a source of debate (Engen, 1982, 1988; Schmidt & Beauchamp, 1992; Steiner, 1979).

The perceived pleasantness of odorants can be altered in a number of ways. Prior exposure of an odorant can modify pleasantness, where previous exposure of a pleasant odor decreases its relative pleasantness, and exposure to an unpleasant odor decreases its relative unpleasantness (Cain & Johnson, 1978). Order of hedonic presentation can modulate perceived hedonic intensity, producing contrast effects (i.e., increases in hedonic ratings) if

odorants are presented in same-valence blocks (Madigan, Ehrlichman, & Borod, 1994). Certain psychophysical components, such as intensity, can also alter perceived pleasantness, where increasing the concentration of an odorant has been shown to decrease ratings of pleasantness for both pleasant and unpleasant odors (for discussion, see Doty, 1991). An exception is Tassinary's (1985) study, who found this relationship only for unpleasant odors.

Interestingly, certain emotion theorists argue that intensity and hedonicity are also related to emotional/motivational experience. As cited by Tucker, Vannata & Rothlind (1990), Berlyne (1971) characterized the relationship between hedonics and stimulus intensity as an inverted U curve. Initially, low levels of intensity generate increases in positive hedonic value, but increases in intensity lead to decreased pleasure and eventually displeasure. Berlyne describes two different functions which characterize the inverted curve: one associated with approach behaviors (the up-slope), exciting the reward mechanisms, and the other with avoidance behaviors (the down-slope), where reward mechanisms are inhibited. The relationship between hedonicity and intensity is also emphasized by Pribram (1980), who proposed that changes in intensity are responsible for altering the one dimension of emotional experience. Likewise, as pointed out by Ehrlichman & Bastone (1992b), several emotion theorists, including Lang and Zajonc, define affective experience by hedonic valence.

Given that odorants are intrinsically pleasant or unpleasant, the hedonic experience is reported to occur with a low level of cognitive involvement (Ehrlichman & Bastone, 1992a, 1992b; Engen, 1982; Izard, 1993; Lang, 1993; Van Toller, 1988). However, pleasantness evaluations can be modulated by cognitive factors and appraisals. Examples of these factors include preconceptions about the odor (Ehrlichman & Bastone, 1992b), and contextual cues,

such as personal experience (see Engen, 1988; Jellinek, 1994) and sensory cues (i.e., color and temperature) (Russek, Fantino, & Cabanac, 1979; Zellner & Kautz, 1990).

Of special interest to researchers in emotion are studies examining the influences of odors on affective experience, mood, emotional facial expression, and motivational tendencies of approach and withdrawal. Techniques include subjective hedonic intensity ratings, direction of lateral eye movements, mood questionnaires, olfactory evoked potentials, psychophysiological measures (e.g., startle probe responses), and overt and covert facial expressions. Such studies suggest that odorants provide a valid means of eliciting affective responses.

Ehrlichman (1987) described three studies conducted in his laboratory to explore hemispheric differences in positive and negative olfactory experiences. Hypotheses were generated based on the theories of hemispheric asymmetries in emotion (e.g., right hemisphere versus valence hypotheses). As olfactory projections are primarily ipsilateral (i.e., right nostril stimulation projects to the right hemisphere), pleasant and unpleasant odorants were presented to either the left or right nostril, and normal subjects were asked to rate the odorant's hedonic intensity. The three studies differed in terms of method of odorant presentation and number of trials. For each study, no differences emerged as a function of nostril presentation. Yet, when the data were analyzed across studies, unpleasant odors were rated as significantly more unpleasant when presented to the right than the left nostril, whereas pleasantness ratings for positive odors did not differ between right and left nostrils.

Ehrlichman (1987) also examined direction of lateral eye movements (LEM) to determine hemisphere activation in response to pleasant and unpleasant odors. In this

paradigm, it is proposed that left LEMs represent right hemisphere activation and right LEMs represent left hemisphere activation. Subjects were videotaped, and LEMs were examined as they smelled the odor; subjects were also asked to rate its degree of pleasantness. Negative odors produced more left LEMs compared to neutral odors, and when left versus right LEMs were examined, higher unpleasant intensity ratings were made for left LEMs. No differences in direction of LEMs were found for the pleasant odorants.

One recent study examined changes in regional cerebral blood flow to hedonic olfactory stimulation (Zald, Pardo & Pardo, 1995). Olfactory stimuli differing in hedonic quality and intensity were birhinically administered to 10 healthy female subjects. Contrary to Erlichman's findings regarding laterality, these authors found an increase in CBF in the left lateral orbitofrontal cortex (Brodmanns' area 47) only to the highly aversive odorants. They also examined hedonic experience to gustatory stimuli. Preliminary data suggested that the same area of activation was found for the aversive gustatory stimuli, thus suggesting that this region is involved in processing aversive tastes as well as olfactory stimuli. However, in terms of the olfactory stimuli, the authors were unsure of the relative trigeminal contributions in the aversive odorants, and thus it is unclear if their findings are related to processing the trigeminal components involved in smell and taste, or to the hedonics of gustatory and olfactory stimuli.

Several studies have examined the role of odors on mood by using a variety of mood questionnaires, including the Differential Emotional Scale (DES) and the Profile of Mood States (POMS). A potential confound in such studies is that they may be fraught with demand characteristics. For instance, if a within-subjects design is used, a subject may presume that pleasant odors should place them in a positive mood, whereas unpleasant odors should place

them in a negative mood. Thus, demand characteristics are minimized in studies using a between-subjects design.

Ehrlichman & Bastone (1992a) asked three separate groups of subjects to rate their mood after a sustained exposure to a pleasant, unpleasant or no odor, on two different types of measures, the first by Likert scales (i.e., if mood was "good" or "bad"), and the second by administering 12 items from the DES. They found that ratings of mood on the Likert scales differed significantly in the expected directions (e.g., better moods reported following exposure to the pleasant odor). On the DES, the groups differed only on the descriptor of disgust, where subjects receiving the unpleasant odors differed significantly from the pleasant and no odor group. In a subsequent study, these investigators tested five groups of subjects that smelled one of two unpleasant odors, one of two pleasant odors or no odor, and then self-assessed their mood using five general scales (e.g., "annoyed-pleased", "disgusted-delighted"). The subjects rated mood at three time intervals during odor presentation (1, 14 and 28 minutes). For both pleasant and unpleasant odors, mood ratings changed immediately after exposure. While this effect remained for unpleasant odors, mood ratings of pleasant odors did not persist. One explanation offered by the authors was the tendency for the pleasantness of pleasant odors to habituate over time. This finding (i.e., habituation) is compelling in that it suggests that demand characteristics have been minimized. If such characteristics were operative, then one would expect mood ratings for pleasant odors to also persist. Thus, the affective change resulting from odorant exposure appears to be related to the psychophysical characteristics of odors.

Two studies completed by Schiffman and her colleagues (Schiffman, Sattely-Miller,

Suggs, & Graham, 1995; Shiffman, Suggs, & Sattely-Miller, 1995) likewise found an increase in mood scores, as measured by the POMS, for pleasant odors in comparison to a placebo (no odor) in middle-aged men and women. For women, four different groups were examined, with groups differing in terms of menstrual status (i.e., pre- versus post-menopausal) and type of hormonal replacement treatment (i.e., estrogen alone versus estrogen and progesterone). Women who were post-menopausal and received estrogen and/or progesterone reported better mood than those post-menopausal women not receiving treatment. One difficulty with these two studies was the use of a within-subjects design. The subjects' mood ratings may have been influenced by expectations, as enhanced mood was reported in the placebo (an odorless spray) versus control conditions. This is confirmed by an earlier study which directly examined demand characteristics of odors on emotional state, by manipulating subjects' expectations of the odorants' effects (Knasko, Gilbert, & Sabini, 1990).

For most of the studies discussed above, odorants can alter self-reported affective states in a manner similar to other mood induction techniques (see Ehrlichman & Bastone, 1992a; 1992b). The validity of these findings are confirmed by research examining responses via physiological measures, such as startle probe responses and chemosensory evoked potentials.

Several studies have examined the modulation of the involuntary startle reflex as a function of hedonic valence, where the reflex is attenuated during positive emotional states and enhanced by negative emotional states (for review, see Lang, Bradley and Cuthbert, 1990). Two studies have specifically examined modulation of the startle reflex as a function of odor hedonics (Ehrlichman, Brown, Zhu & Warrenburg, 1995; Miltner, Matjack, Braun, Diekmann,

& Brody, 1994). Both studies found a significant potentiation of the reflex during the unpleasant odor condition in comparison to the pleasant and no odor conditions, whereas no differences in the response were found for the pleasant versus no odor condition.

Other differences as a function of pleasantness have been observed in evoked potential studies by Kobal and his colleagues (Kobal & Hummel, 1992; Kobal, Hummel, & Van Toller, 1992). Differences in evoked potentials to four odorants (carbon dioxide, menthol, hydrogen sulphide and vanillin) for right versus left nostril presentation were observed. After administration to the left nostril, responses to carbon dioxide, hydrogen sulphide and menthol showed significantly shorter latencies and smaller amplitudes (Kobal et al., 1992). In contrast, after stimulation of the right nostril, responses to vanillin had shorter late component latencies and smaller amplitudes. Differences in the evoked potentials to the odorants were thought to be related to their hedonicity, since vanillin was the only odorant consistently rated as pleasant. As it is difficult to interpret the meaning of these amplitude and latency changes in terms of hedonics and hemispheric asymmetries, a subsequent study was conducted (Kobal & Hummel, 1992). Subjective ratings of several odorants were examined, with two being perceived as pleasant (phenylethyl alcohol, low concentration of acetaldehyde) and two as unpleasant (hydrogen sulphide, high concentration of acetaldehyde). After left nostril stimulation, odorants were perceived as more pleasant, and amplitudes became larger and latencies longer. This relationship was also observed with the varying concentrations of acetaldehyde. Thus, the authors suggest that the differences observed were related to the affective aspects of the odors. Since olfactory projections are ipsilateral, these differences partially support the valence hypothesis of emotional processing.

Facial Expressions. Similar to studies in emotion examining expressive behaviors during different affective states, spontaneous and voluntary facial expressions in response to olfactory and gustatory stimuli have been explored. According to Pfaffmann and colleagues (Pfaffmann, Norgren, & Grill, 1977), three types of behavioral responses can result from sensory hedonic experience: approach/acceptance, rejection/withdrawal, and neutrality/indifference. In terms of behaviors occurring with these responses, an early study examining facial expressions to odorants in adults noted that liking an odor included such responses as smiling, nodding, opening the mouth, and taking longer and deeper sniffs, whereas expressions of dislike included turning of the head and body, jerking the head back suddenly, wrinkling the nose, raising the lip, and shaking the head (Kniep, Morgan, & Young, 1931). At face value, opening of the mouth and sniffing appear to be behaviors related to approach, whereas those of turning the head and body and jerking the head away from the odorant are behaviors indicative of withdrawal or avoidance. Thus, detailed observations may be useful in determining differences in approach and withdrawal behavior related to olfactory hedonics. However, in an earlier study examining responses in infants to hedonic olfactory stimuli, no differences in withdrawal responses emerged, even though other behavioral differences (e.g., startles, grimaces) were found (Self, Horowitz, & Paden, 1973).

Steiner published a series of articles examining facial expressions of the neonate to hedonic stimuli (1974; 1977; 1979) and argued that facial responses to olfactory and gustatory stimuli were reflexive in nature. Furthermore, Steiner contended that facial reflexes to hedonic stimuli were innate and occurred in a stereotypical manner. He described two specific types of neonatal facial responses associated with pleasant and unpleasant odorants (Steiner, 1974), but

it is unclear how these features were determined. Pleasant odors resulted in "relaxation of the face, retraction of mouth angles, resembling 'smiling' expression accompanied by sucking-licking movements" (p. 231). Unpleasant odorants resulted in spitting movements, salivation, and a facial response similar to that elicited to bitter tastes -- "depression of the mouth angles with simultaneous or subsequent elevation of the central part of the upper lip, creating an 'arch-like' mouth opening" (p. 229), which resembled disgust or aversion reactions in adults. He reports similar types of responses in a hydroanencephalic infant lacking cortical and forebrain structures (Steiner, 1977; 1979).

In one study (Steiner, 1977), six adult raters were asked to judge infants' responses in terms of acceptance, rejection or indifference to odorants judged by adults to be unanimously pleasant or unpleasant. While there was high agreement among the judges for the infants' responses to the unpleasant odor, there was less agreement for responses to the pleasant odors. Nevertheless, he believed that facial expressions were intrinsic to the brainstem, and that there was a "hedonic monitor system" (Steiner, 1979, p. 261) which could determine the acceptability of stimuli. Accordingly, Steiner believed that pleasant stimuli lead to positive hedonic evaluations, evoking pleasant emotional states and displays of smiles, whereas unpleasant stimuli increase negative hedonic states that evoke facial displays of disgust.

Recent studies with adults do not support Steiner's contention that facial displays automatically accompany hedonic evaluations. Gilbert, Fridlund, & Sabini (1987) found minimal spontaneous facial movement in response to odors, where subjects were unaware that their responses were being videotaped. In this study, when subjects were aware that responses were videotaped in a subsequent condition and were asked to pose expressions to the odorants,

accuracy ratings by naive judges significantly improved, and responses to unpleasant odorants were classified more accurately than to pleasant odors. This decrease in accuracy in response to pleasant odors was not due to the posers' lack of hedonic experiences, as only data from posers who correctly classified the hedonic quality (assessed by subjective hedonic ratings) were used. Similarly, Jancke & Kaufmann (1994) found no significant correlation between facial electromyograph (EMG) responses and subjective hedonic ratings. In contrast, Kraut (1982) reported that spontaneous facial expressions can provide graded information about internal states, as evidenced by the correlation analysis between subjective ratings and facial expressions, with higher correlations obtained for spontaneous than for posed expressions. Likewise, Tassinary (1985) reported differential effects on facial activity, measured by muscle action units (AUs), as a function of odor valence and intensity, with greater activation of AUs associated with smiling to weakly pleasant odors and greater activation of AUs related to nose wrinkling or snarling to highly unpleasant odors.

Presence or absence of an audience can also alter expressions in response to gustatory and olfactory stimuli, but findings are variable. As cited by Kraut (1982), Brightman and his colleagues (Brightman, Segal, Werther, & Steiner, 1975, 1977) focused on facial expressions to gustatory stimuli and found that raters were able to determine whether the subjects were eating salty or sweet food when others were present, in contrast to the same food eaten in solitude. However, Kraut (1982) did not observe this effect, and in his study, presence of another appeared to inhibit facial expressions. Jancke and Kaufman (1994) found increases in facial EMG activity (e.g., M. nasalis, M. levator) only to highly unpleasant odors when the subject was alone, with no change in facial EMG activity for pleasant odors. However,

changes in facial EMG activity (e.g., M. zygomaticus, M. obicularis oculi) to pleasant odors were seen when subjects were aware that they were being observed. Presence of another also altered findings in a study by Soussignan & Schaal (1996), who examined facial responsiveness to odors in children. Facial displays to unpleasant odors were more accurately categorized by naïve raters when children were alone versus when an unfamiliar adult was present. For pleasant odors, facial responses were rated more accurately and as being more intense when the child was in the presence of an unfamiliar adult than when the child was alone.

Summary. Odorants are useful in eliciting hedonic experience and mood in an ecologically valid manner. Olfactory stimuli also seem to produce differential valence effects in physiological and facial expression studies. In addition, they are attractive stimuli to use in studies of emotion because minimal cognitive effort appears to be required to determine their hedonic tone. Thus, they may be useful as stimuli in studies examining emotional processing, especially in subjects who are likely to have cognitive impairments.

Neuroanatomical Substrates of the Olfactory System

Olfaction has been an area of intense interest, and a number of recent studies have examined olfactory functions in different neurological and neuropsychiatric populations. This review will focus on the pathways and neuroanatomical substrates of the olfactory system, as well as on studies examining olfactory functions in patients with focal brain lesions, in order to explain the methodology used in the current study (i.e., odorant presentation) and to better interpret results.

Olfactory Pathways. Processing of olfactory information begins at the olfactory

neurons, located in the olfactory epithelium in the nasal cavity. These olfactory neurons contain receptor proteins extending from the cilia, which extend outward and are in contact with the overlying mucous. Based on findings by Buck and Axel (1991) using molecular genetic techniques, approximately 1,000 different genes encode 1,000 different olfactory receptors; this contrasts dramatically with the visual system, where only four different receptors (i.e., rods, three types of color cones) have been identified. It appears that each discriminable odorant activates a unique population of receptor cells and that the size of the population of activated cells may be dependent upon the concentration of the odorant (Scott, 1991).

Olfactory neuron axons project through the cribiform plate to the paired olfactory bulbs. In the bulb, these axons synapse with both interneurons and output cells (i.e., mitral, tufted cells) in discrete structures called glomeruli, which receive feedback information from other interglomerular neurons (Scott & Harrison, 1991). It appears that each glomerulus acts as a functional unit, dependent upon the type of odorant receptor activated (Scott, 1991). Second-order neurons (i.e., mitral and tufted cells) then project through the olfactory tract, which divides into the lateral, medial, and intermediate olfactory stria.

The major centripetal olfactory pathway is the lateral stria. Direct projections via the lateral stria are sent ipsilaterally to higher-order olfactory regions, including the anterior olfactory nucleus, the olfactory tubercle, the prepiriform cortex, the periamygdaloid cortex, the entorhinal cortex, and the hypothalamus (Brodal, 1981; McLean & Shipley, 1992). Projections through the medial stria become continuous with the subcallosal area and the paraterminal gyrus, which together constitute the septal area (Carpenter, 1984), although no projections to the septum have been reported (Eslinger, Damasio, & Van Hoesen, 1982). The intermediate

stria appears to join the anterior commissure and connect the ipsilateral olfactory bulb to the contralateral olfactory bulb and anterior olfactory nucleus (Eslinger et al., 1982). A simplified diagram of the olfactory pathway (via the lateral and intermediate stria) is provided in Figure 1 (adapted from McLean & Shipley, 1992).

The prepiriform cortex has a frontal and temporal element, located on the posterior orbitofrontal and mesial temporal lobe surface (Eslinger et al., 1982). Prepiriform, periamygdaloid, and entorhinal cortices collectively form the piriform cortex (Brodal, 1981). These structures, as well as the anterior olfactory nucleus and the olfactory tubercle, constitute the primary olfactory cortex (McLean & Shipley, 1992). From the olfactory cortex, information is also sent to the dorsomedial and submedial nuclei of the thalamus, the ventral agranular insular area, the lateral hypothalamus, the amygdala and the hippocampus (Price, 1991; Otto & Eichenbaum, 1992). The orbitofrontal cortex receives direct projections from primary olfactory cortex, as well as indirect projections via the dorsomedial and submedial thalamus (Powell, Cowan, & Raisman, 1965).

The projections from the olfactory bulbs are predominantly ipsilateral, but there are contralateral connections via the anterior commissure from the anterior olfactory nucleus; this structure sends projections to the ipsilateral and contralateral olfactory bulb (Brodal, 1981). The functional significance of these contralateral connections in human olfactory functioning is unclear, but there appears to be some bilateral summation, as seen by cross-modal performance abilities in olfactory studies of two callosotomy patients with intact anterior commissures (Eskanazi, Cain, Lipsitt & Novelly, 1988). Likewise, performance is better under bilateral than unilateral stimulation conditions, as seen on tasks of suprathreshold intensity perception,

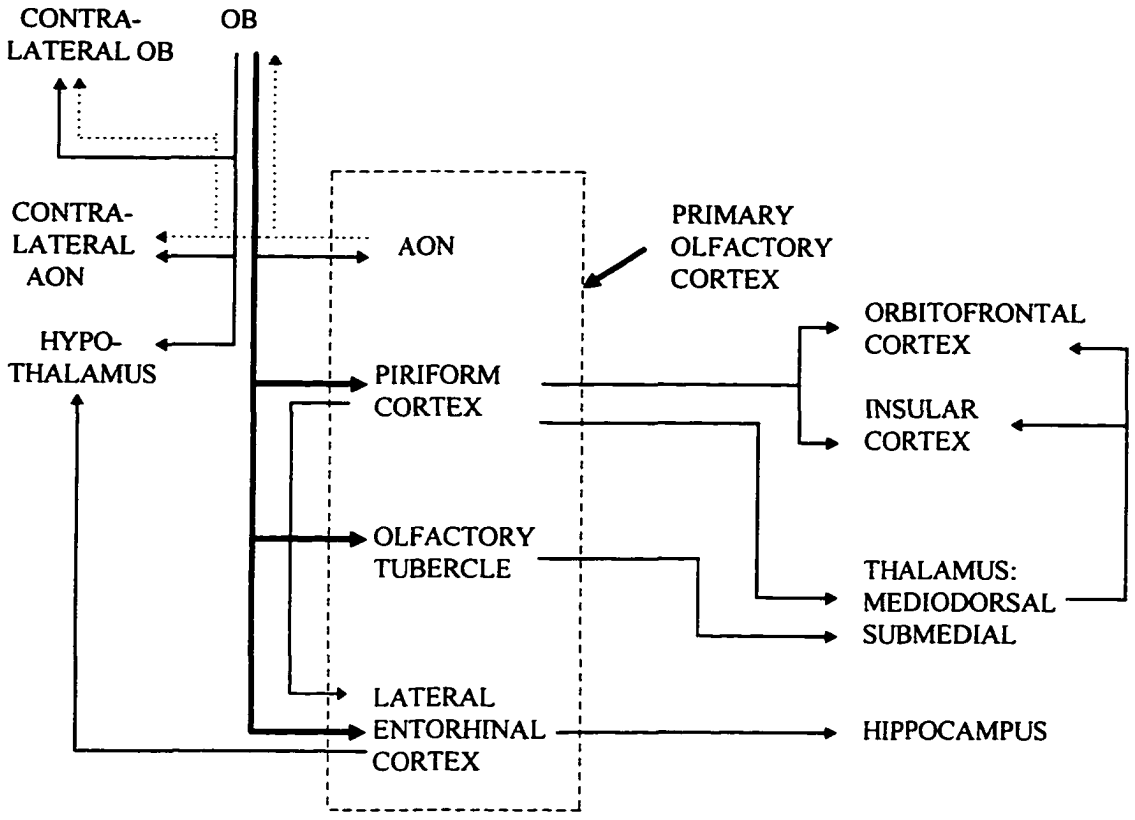


FIGURE 1. Major afferent connections of the olfactory system. Regions within the dashed lines are within the primary olfactory cortex. OB, olfactory bulb; AON, anterior olfactory nucleus.

Note. From "Neuroanatomical Substrates of Olfaction," (p. 146), by J. H. McLean and T. Shipley, in Science of Olfaction (M. J. Serby & K. L. Chobar, Eds.), 1992, New York: Springer-Verlag. Copyright 1992 by Springer-Verlag, Inc. Adapted with permission.

identification and memory (Bromley & Doty, 1995; Cain, 1977; Doty, Stern, Pfeiffer, Gollomp, & Hurtig, 1992).

Despite some crossover of olfactory information, each hemisphere appears to have the ability to process olfactory information. For instance, patients with complete commissurotomies, with surgery which includes the anterior commissure, are able to recognize odors in the hemisphere ipsilateral to the nostril stimulated (Gordon, 1979; Gordon & Sperry, 1969). Furthermore, the findings from this study indicate that the posterior nasal passages are relatively separated, as subjects were able to name odorants presented to the left nostril, but not to correctly point to them with the left hand, and to correctly point to an object corresponding to their smell experience with their left hand when odorants were presented to the right nostril but not correctly name it. As reviewed above, several studies have used unilateral presentations to examine hemispheric contributions to olfactory hedonics. Therefore, just as dichotic listening and tachistoscopic procedures have been used to examine hemispheric contributions in auditory and visual processing, monorhinic presentations appear to be a useful way of examining hemispheric asymmetries in olfactory processing.

The similarity between the neural systems involved in olfaction and emotion is striking. Neural structures identified in olfaction, emotion and motivation include the amygdala, hippocampus, hypothalamus, prepyriform cortex and orbitofrontal cortex (for review of anatomical structures in emotion, see Damasio & Van Hoesen, 1983; Derryberry & Tucker, 1992; Macchi, 1989; Papez, 1937). Yet, as noted by Ehrlichman & Bastone (1992b), caution should be exercised in presuming that anatomical relationships necessarily imply psychological relationships. As they point out, it would be incorrect to assume "that olfaction is 'more

directly involved' in amygdalar function than are more highly processed signals emanating from the visual receptors" (p. 422), just because the olfactory bulbs have more direct projections to this structure than other sensory systems. Indeed, there are studies which suggest the existence of projections from subcortical visual pathways to the amygdala (LeDoux, 1993). Likewise, the circuitry for projections from subcortical auditory pathways to the amygdala have been confirmed, and their role in emotional learning have been elucidated (LeDoux, 1993). Clearly, more psychological research is needed to better understand the anatomical connections between the olfactory system and neural substrates identified in emotional processing.

Hemispheric Asymmetries in Olfactory Functions. Similar to structural and functional hierarchies in other sensory systems, animal studies suggest that piriform and orbitofrontal cortices correspond to primary and secondary regions (Takagi, 1991). Organization of the olfactory system in humans is not as well-understood, but, a number of studies have examined the effects of brain lesions resulting from neurosurgical ablation (lobectomy) or vascular insult. These studies have assessed performance on odor detection, odor discrimination, odor identification and odor memory tasks.

For odor sensitivity, measured by noting alterations in detection thresholds, the majority of studies have not found any significant asymmetries as a result of brain damage (Eichenbaum, Morton, Potter, & Corkin, 1983; Eskanazi, Cain, Novelly & Friend, 1983; Eskanazi, Cain, Novelly & Mattson, 1986; Jones-Gotman & Zatorre, 1988; Martinez et al., 1993; and Potter & Butters, 1980), with one exception (Rausch & Serafetinides, 1975). Damage to structures in the orbitofrontal region and medial temporal lobe structures (e.g., temporal prepiriform cortex, amgydala) caused impairments in perception of odor quality (i.e.,

quality discrimination, identification, and memory) (Eichenbaum et al., 1983; Eskanazi et al., 1983; Eskanazi et al., 1986; Jones-Gotman & Zatorre, 1988, 1993; Martinez et al., 1993; Potter & Butters, 1980; Rausch, Serafetinides & Crandall, 1977; and Zatorre & Jones-Gotman, 1991). However, certain tasks, such as odor memory, may be adversely affected by dysfunction in other brain regions (Carroll et al., 1993).

Recent investigations have examined hemispheric contributions to olfactory information processing, in both normal and brain-damaged subjects. Hemispheric asymmetries in olfactory functioning are less clear-cut, and depend upon the function (e.g., discrimination, identification) being assessed. Some studies with subjects with focal lesions have found no lateralized effects (Eskanazi et al., 1983; Eskanazi et al., 1986; Jones-Gotman & Zatorre, 1988; Rausch & Serafetinides, 1975), whereas others indicate an asymmetry favoring the right hemisphere (Abraham & Mathai, 1983; Carroll et al., 1993; Jones-Gotman & Zatorre, 1993; Martinez et al., 1993; Rausch, Serafetinides & Crandall, 1977; Zatorre & Jones-Gotman, 1991). When odorants were presented unilaterally, some investigators found deficits to be more pronounced if odorants were administered to the nostril ipsilateral to the lesion (Eskenazi et al., 1983; Martinez et al., 1993; Zattorre & Jones-Gotman 1991). There are also findings from normal control subjects, indicating a relatively greater right hemisphere contribution in processing olfactory information (Zucco & Tressoldi, 1988; Zatorre & Jones-Gotman, 1990, 1992; Zatorre, Jones-Gotman, Evans, & Meyer, 1992). Although Zatorre et al. (1992) report unilateral activation in the right orbitofrontal cortex using PET, they also found activation in the left medial frontal lobe, possibly representing the frontal portion of the piriform cortex. Overall, it seems that for some olfactory tasks, there may be some specialization favoring the

right hemisphere, but given the variability in findings between studies, this interpretation remains to be conclusively demonstrated.

Objectives and Hypotheses of the Study

As evident from the literature reviewed, the respective contributions of the left and right cerebral hemispheres in emotional processing are not clearly understood. The asymmetries observed for specific emotional dimensions (e.g., valence) appears to depend upon the component of emotion examined (e.g., perception versus experience). Yet, when studies examining similar components (i.e., perception of prosodic stimuli, emotional facial expression) are compared, there are still discrepancies, especially in those studies using subjects with unilateral lesions. Furthermore, findings and interpretations regarding hemispheric asymmetries observed in normal and patient populations are difficult to reconcile. Most of the evidence, however, from normal subjects and from patients with unilateral lesions, suggests that the right hemisphere plays a predominant role in facial and prosodic emotional perception and emotional facial expression (Borod, 1992, 1993).

There is less evidence supporting the view that emotional experience is dependent on right hemisphere systems. In fact, much research in normal subjects and in subjects with unilateral lesions suggests differential contributions of the right and left hemispheres in experiential and mood studies. The most consistent finding which has been observed is along the anterior-posterior axis, with anterior brain regions being more involved in emotional experience. Some have argued that the "dimension of emotional valence depends most closely on the right hemisphere's level of functioning. This is the dimension of mood level, varying

from depression to elation" (Tucker & Frederick, 1989, p. 59). Thus, perhaps the right hemisphere is, in a sense, more "emotional" than the left hemisphere.

The mood disturbances observed in patients with unilateral lesions may be separate from dysfunctions in emotional experience, which has not been well studied. Laboratory methods used to elicit experience/expression often require much cognitive effort (e.g., imagery techniques, perceptual tasks) to induce an experiential/expressive state. This is especially significant for those studies using patients with unilateral lesions, where the lesion may also result in cognitive deficits. The use of odorants to induce emotional states may provide an ideal means to bypass such difficulties, given that odors have an intrinsic hedonicity, so minimal cognitive effort is required to extract the hedonic information. Research suggests that they are a valid means of examining emotional experience and facial expression.

This study examined both hedonic experience and facial expression in normal control subjects, and in subjects with right-hemisphere damage (RHDs) and with left-hemisphere damage (LHDs). The majority of RHD and LHDs subjects in this study had lesions involving neocortical structures, as previous research with subjects having unilateral lesions suggest the importance of the neocortex in emotional processing. Inter- and intra-hemispheric contributions to hedonic experience and expression were explored, by examining performance on a subset of subjects having either lesions involving only posterior brain regions or lesions involving anterior and posterior brain regions. Valence effects were assessed via pleasant and unpleasant odorants. Group performances were compared for subjective ratings to the odors. In addition, videotapes of spontaneous and prompted (i.e., voluntary) facial expressions to the odorants were evaluated by naive raters. Performance for subjective hedonic ratings and facial

responses to odors was analyzed by noting the presence of a hedonic response (i.e., if the odor was pleasant or unpleasant versus neither pleasant nor unpleasant), accuracy in identifying the hedonic quality of the odorant administered, and hedonic intensity (i.e., intensity of the experience and of the facial response).

For spontaneous expressions, responses were also examined for presence of withdrawal/avoidant responses. One study in patients with unilateral lesions (Mammacuri et al., 1988) found that RHDs made fewer avoidant responses (gaze aversions) to unpleasant visual stimuli. Some investigators argue that an important dimension of emotion concerns approach and withdrawal action tendencies, and that the right and left cerebral hemispheres are differentially involved in these action tendencies. Although studies have used the lesion method to examine hemispheric differences regarding valence, there are no studies to date directly examining differential action tendencies in subjects with unilateral lesions. Some studies with infants have noted the occurrence of withdrawal responses to odors. Therefore, subjects' responses were examined by the raters for presence of avoidant responses during odorant presentations.

There were several objectives for this study. It was of interest to determine if odorants could evoke hedonic experience and facial expression in a manner similar to other elicitation methods used in patients with unilateral lesions. Group comparisons were made investigating differential responses to odors, namely, spontaneous and prompted facial expressions, subjective ratings, and differences in behavioral choice measures (which required the selection between a pleasant and an unpleasant odor). These group comparisons were evaluated to determine if the findings supported or refuted different neuropsychological theories of emotion,

specifically, the right hemisphere and valence hypotheses. As both subjective ratings and facial responses were obtained for each subject, the nature of the relationship between intensity of experience, spontaneous expressions, and prompted expressions was investigated, to determine if these components were interrelated or dissociable. Lastly, the role of the right hemisphere in withdrawal action tendencies was examined.

Statement of Hypotheses

The hypotheses evaluated were as follows:

The right hemisphere hypothesis

The right hemisphere plays a predominant role in emotional facial expression and experience/expression.

1. Facial responses to odors produced by participants with RHD would be less expressive than facial responses produced by the LHDs and NCs, regardless of odor valence. Performance was assessed by naïve raters who evaluated the facial expression data. From the raters' evaluations, it was determined: (1) whether or not the subject made an expression indicating that the subject was smelling a pleasant/unpleasant odor versus an odorant which was neither pleasant nor unpleasant (responsivity); (2) whether or not the hedonic quality of the subject's expression was judged to be consistent with the experimental categorization of the odor (i.e., pleasant versus unpleasant); and (3) the hedonic intensity of the expression, based on the degree of musculature involvement in the facial expression.
2. Subjective hedonic ratings of RHDs would differ from ratings of LHDs and healthy

controls, in that ratings made by RHDs would be less responsive, less accurate and less intense than LHDs and controls. Similar to measures for facial expression, performance was assessed in three ways: (1) whether or not subjects found odors to be pleasant/unpleasant or neither pleasant nor unpleasant (responsivity); (2) the tendency in judging the hedonic quality of the odor, to agree with a priori classifications of the odor's pleasantness or unpleasantness (accuracy); and (3) the degree of pleasantness or unpleasantness of each odor (intensity).

3. On a behavioral choice measure, where participants were asked to chosse between pleasant and unpleasant odors, it was expected that participants with RHD would choose fewer pleasant odors than the LHD and NC subjects.

The valence hypothesis

The left hemisphere is specialized for positive emotions, and the right for negative emotions.

1. Facial responses to pleasant odors made by the LHDs would be less expressive than expressions produced by the RHDs and controls. Hedonic facial expressions to unpleasant odors produced by the RHDs would be less expressive than LHDs and controls. The three performance measures (responsivity, accuracy and intensity) described above were assessed.
2. Subjective hedonic ratings of LHDs to pleasant odors would be less responsive, accurate and intense than RHDs and controls. Conversely, subjective hedonic

ratings of RHDs to unpleasant odors would be less responsive, accurate and intense than LHDs and controls.

The approach-withdrawal hypothesis, stressing action tendencies

The right hemisphere subserves withdrawal/avoidant action tendencies.

Patients with right hemisphere lesions would demonstrate fewer withdrawal responses to the odors during spontaneous facial expression conditions than patients with left hemisphere lesions and normal control subjects.

The following secondary hypotheses were also examined:

Anterior brain regions play a greater role in emotional expression and experience than posterior regions.

Subjects with lesions involving anterior brain regions would be less expressive and would make experiential ratings which were less responsive, accurate and intense relative to participants with only posterior lesions.

Hedonic experience and expression are related components.

An association would be seen between subjective ratings of odors and spontaneous expressions and prompted expressions to odors for all three groups.

METHODS

Participants

Subjects were 21 patients with unilateral right-hemisphere damage (RHD) (15 men, 6 women), 19 patients with left-hemisphere damage (LHD) (9 men, 10 women), and 18 matched neurologically healthy control subjects (11 men, 7 women). Potential participants were recruited from several sites. Brain-damaged subjects were Neurology outpatients at Mount Sinai Medical Center in New York City, rehabilitation inpatients from Gaylord Hospital in Connecticut, and outpatients from stroke clubs in the New York City and Long Island areas. Recruitment of healthy participants was by newspaper advertisement and by advertisements posted at local hospitals, community centers, and senior citizen centers. Informed consent was obtained, and subjects were paid for their participation.

For the experiment, 73 subjects in total were tested (i.e., LHDs, RHDs and NCs). Out of the 54 LHD and RHD subjects tested, 14 subjects did not complete the experimental procedures for a number of different reasons: 4 were discharged and were unable to return to complete the experiment, 4 were anosmic (by the criterion of this study), 3 had moderate/severe receptive aphasia, and 3 declined to participate after testing was begun (2 subjects found the odorants too unpleasant, 1 subject's family did not want her to participate). One control subject was tested but excluded due to a history of neurological disorder not known when testing began.

For Condition 5 (spontaneous expressions to highly unpleasant odors), only a subset of the original sample participated, as subjects were told that some people might find the odors

very unpleasant, and could decline to participate. Due to technical problems, 5 subjects (1 LHD, 3 RHDs and 1 NC) were not administered this set of odorants; 12 subjects declined to participate (3 LHDs, 6 RHDs and 3 NCs). Thus, subjects for this condition consisted of 15 LHDs, 12 RHDs, and 14 NCs.

Selection Procedures. For the two patient groups, only subjects with unilateral brain lesions of cerebrovascular origin (CVA) (i.e., infarction or hemmorhage) were recruited for the study. Other selection criteria included: (a) at least 4 weeks post CVA onset; (b) no intracranial surgical history; (c) no history of documented anosmia; (d) no history of chronic asthma, chronic obstructive pulmonary disease, chronic sinusitis, or serious allergic reactions; (e) no history of alcohol or substance abuse; (f) no premorbid history of psychotropic drug treatment or psychiatric disorder; and (g) no history of other neurological disorders (e.g., Parkinson's disease, dementia, multiple sclerosis, moderate to severe head trauma, epilepsy). Hand preference was noted by using four items from a self-report inventory (Coren, Porac & Duncan, 1979).

The normal control subjects were matched to the patients for gender, age, education, occupation, and ethnicity and met criteria (c) through (g) listed above. Means, standard deviations, and frequencies for the demographic variables for the 3 groups are shown in Table 1. The three groups of subjects did not differ in any subject characteristic (age [$F = 1.09$; $df = 2,57$; $p = .81$]; education [$F = 1.09$; $df = 2,57$; $p = .34$], occupation level [$F = .91$; $df = 2,57$; $p = .41$], or gender [Chi square = 2.14, $p = .30$].

LHDs and RHDs did not differ in terms of months post onset (MPO) ($t = .05$, $df = 38$,

p = .96). However, as intrahemispheric effects were of interest (see the next section describing the LHD and RHD groups), an analysis was done to compare MPO as a function of group and lesion site (i.e., posterior only versus anterior plus posterior). A two-way ANOVA indicated a significant main effect for lesion site ($F = 6.29$; $df = 1,28$; $p = .02$), with the posterior only group ($\underline{M} = 7.5$ months) being tested sooner post-stroke than the anterior plus posterior group ($\underline{M} = 27.7$ months).

Table 1. Demographic Information for Each Subject Group

Variable	Subject Group		
	LHD (n = 19)	RHD (n = 21)	NC (n = 18)
Gender (males/females)	9/10	15/6	11/7
Age (years)	61.5* (11.8)	63.8 (13.1)	62.8 (8.9)
Education (years)	14.8 (3.0)	13.5 (2.6)	14.3 (2.9)
Occupation Level**	6.3 (2.2)	6.0 (2.4)	5.3 (2.2)
Months post-onset	16.2 (17.9)	16.6 (26.4)	---

* Mean (s.d.)
** From Hollingshead-Redlich (1958) scale

Description of LHD and RHD Groups. The majority of patients had lesions involving neocortical structures, as documented by CT/MRI brain scans. Subject characteristics are described in Tables 2 and 3. Neurological status obtained from medical records at the time of CVA onset was used to indicate the presence (+) or absence (blank) of hemiparesis, facial paresis, sensory loss, visual field deficit, and unilateral visual neglect. Analyses revealed that

Table 2. Subject Characteristics of Right-Hemisphere Damaged Subjects

Case No.	Gender	Age	Lesion site*	Lesion description from CT/MRI scan report	Clinical neurological status: Hemi-paresis	Facial paresis	Sensory loss	Visual field deficit	Visual neglect
1.	F	68	P, sub	Temporal, parietal, basal ganglia	+		+	+	+
2.	M	62	P, sub	Temporal parietal region, basal ganglia	+	+	+	+	+
3.	F	75	A + P	Frontal, parietal	+	+	+		+
4.	M	79	sub	Basal ganglia	+		+		+
5.	M	50	A + P, sub	Frontal, temporal, parietal, subcortical	+	+	+		
6.	F	61	P, sub	Parietal, basal ganglia	+				
7.	M	61	A, sub	Frontal, basal ganglia	+		+		+
8.	M	78	P, sub	Occipital, internal capsule	+		+		+
9.	M	53	A + P, sub	Anterior parietal, infarct in MCA and ACA distribution	+	+	+		+
10.	M	68	unk	CVA; negative scan	+	+	+		
11.	M	62	A + P	Frontal, parietal	+	+	+	?	+
12.	M	57	A + P	Frontoparietal convexity in region of sylvian fissure	+		+		
13.	F	29	sub	Basal ganglia, thalamus	+	+			+
14.	M	83	A + P	Opercular region infarct	+	+	+		+
15.	M	72	A	Frontal in region of superior frontal gyrus	+				
16.	M	64	P	Temporal, parietal	+	+	+	+	+
17.	F	50	P	Parietal	+	+	+		
18.	M	48	P	Superior parietal, occipital			+		
19.	F	66	P	Posterior temporal, occipital			+	+	
20.	M	76	A + P	Frontal, temporal, parietal	+	+			
21.	M	78	A + P	Frontal, temporal	+	+	+		

*A = anterior; P = posterior; A + P = anterior and posterior; sub = subcortical, ukn = unkown
+ = presence of a deficit; ? = unknown

Table 3. Subject Characteristics of Left-Hemisphere Damaged Subjects

Case No.	Gender	Age	Lesion site*	Lesion description from CT/MRI scan report	Clinical neurological status: Hemi-paresis	Facial paresis	Sensory loss	Visual field deficit	Visual neglect	Presence of language difficulties (e.g., aphasia)
1.	F	56	P, sub	Parietal, internal capsule	+		+		+	
2.	M	45	P, sub	Parietal operculum, basal ganglia, putamen, capsular region	+		+		+	+
3.	M	79	sub	Basal ganglia, corona radiata	+	+				
4.	F	44	A + P	Frontal, parietal	+	+	?	+		+
5.	M	49	A + P	Occlusion of internal carotid artery at level of bifurcation	+	+	+			+
6.	M	70	sub	Basal ganglia, deep white matter	+	+	+			
7.	M	61	P, sub	Parietal, basal ganglia	+	+				+
8.	M	72	P	Parietal	+	+	+			+
9.	F	43	P, sub	Perisylvian region extending to peri-ventricular white matter to parietal cortex	+	+	+		+	+
10.	M	71	A + P, sub	Frontal, parietal, external capsule, insula	+	+	+	+		+
11.	F	66	P	Mid-temporal	+		+			
12.	M	69	A + P, sub	Posterior frontal, parietal, subcortical, frontal operculum	n/a	n/a	n/a	n/a	n/a	+
13.	F	72	A + P, sub	Frontal, parietal, subcortical	+		+			
14.	F	45	P, sub	Temporal, parietal, basal ganglia	+	+	+	+		+
15.	M	70	P	Temporal						+
16.	F	52	A + P	Frontal, temporal	+	+	+			+
17.	F	69	A + P	Frontal, temporal, parietal	+	+		+		+
18.	F	59	sub	Internal capsule, thalamus	+					
19.	F	75	A + P	Frontal, temporal	+	+		+		+

*A = anterior; P = posterior; A + P = anterior and posterior; sub = subcortical, ukn = unknown

+ = presence of a deficit; n/a = not available

LHDs and NCs did not differ in terms of presence of hemiparesis (Fisher's Exact Test = .56), facial paralysis (Chi square = .18, p = .67), sensory loss (Fisher's Exact Test = .52), and visual field deficit (Fisher's Exact Test = .27). However, unilateral visual neglect (Chi square = 4.18, p = .04) was observed more frequently in RHDs than LHDs (RHDs = 48%; LHDs = 20%). For the individuals with LHD, 68% of the participants were noted to have language difficulties (i.e., aphasia) at the time of CVA onset.

To explore intrahemispheric contributions to subjects' responses, the subjects with brain lesions were also grouped according to lesion site, where lesion location could be classified as involving anterior cortical brain regions (i.e., frontal); posterior cortical brain regions (i.e., parietal, temporal, and/or occipital); both anterior and posterior cortical regions (i.e., frontal-temporal, frontal-parietal, or frontal-temporal-parietal), or subcortical regions (e.g., thalamus or basal ganglia). In one case, the CT scan was negative, so clinical data from neurological examination were used to determine the unilateral nature of the lesion. In order to explore intrahemispheric differences in hedonic experience and expression, 32 subjects from the LHD and RHD group were sub-grouped as having either anterior plus posterior neocortical lesions (8 LHDs, 8 RHDs) or only posterior neocortical lesions (8 LHDs, 8 RHDs). Lesion information for all subjects is provided in Tables 2 and 3.

Research Design

Subjects were tested individually by the same examiner for both screening and experimental measures. Testing was done over one or two sessions, with the first session

beginning with the screening measures. If two sessions were needed, the sessions were usually scheduled one week apart. The entire study took approximately 2-1/2 hours to complete, and subjects were given breaks as needed.

Both pleasant and unpleasant odorants were presented monorhinically in order to enhance any possible laterality effects. As both spontaneous and posed facial expressions were of interest, all subjects were videotaped during the experiment, so that expressions elicited could be later rated by naive judges. Three separate conditions were included to elicit facial displays: spontaneous facial expressions, prompted facial expressions, and spontaneous facial expressions to highly unpleasant odors. One condition was included to obtain hedonic experience of the odors, consisting of subjective ratings of hedonic valence and intensity. Finally, a behavioral choice measure was included to examine goal-directed activity and the ability of the subjects to anticipate the consequences of their choice behavior. Here, a subject was required to choose one odorant from three pairs of different stimuli, with each pair consisting of a pleasant and unpleasant odor. Subjects were told to choose one of the two odors which they would "smell later on in the study". Thus, the experiment consisted of five separate conditions.

In addition, several measures were included to assist in the interpretation of the experimental results. Non-emotional facial factors examined which might influence the results included side and extent of facial paralysis and presence of buccofacial apraxia. Ability to pose emotional and hedonic facial expressions to commands was also investigated to compare performance to facial responses to odors. For example, participants were asked to pose

expressions depicting emotional states (e.g., fear, disgust), as well as to pose pleasant and unpleasant expressions. Subjects were videotaped while performing these tasks, so that these facial movements and expressions could also be later analyzed by trained raters.

Materials

Odorants. Three pleasant and three unpleasant odors were used, based on previous work examining hedonic quality and intensity on a larger set of odorants (see Madigan, Ehrlichman & Borod, 1994). The basis for selection of these six odorants was that: (1) at least 80% of the 20 subjects participating in the Madigan et al. (1994) study agreed upon the hedonic quality of the odorant (i.e., whether the odorant was pleasant or unpleasant); (2) the average hedonic ratings for the odorants were in the middle range of hedonic intensity, to minimize ceiling or floor effects for the experimental measures; and (3) the odorants were not so concentrated as to be likely to stimulate the trigeminal nerve. In addition, the average ratings of hedonic intensity for the three pleasant odors were matched to those of the three unpleasant odorants, by selecting odorants perceived to be in the moderate range of hedonic intensity (see Appendix 1, Table 56). This was done in order to minimize any hedonic effects due to differences in perceived intensity, given the relationship between judgments of odor pleasantness and of odor intensity (for discussion, see Cain, 1988; Doty, 1991; see also, Tucker, Vannatta, & Rothlind, 1990).

The third point raised in odorant selection was prompted by the fact that odorants can be detected by receptors from both the olfactory and trigeminal nerves. Odorant detection by

the trigeminal nerve produces pungent sensations, like irritation, burning or freshness, and these sensations are referred to as the common chemical sense (Cometto-Muniz & Cain, 1991; Silver, 1991). Odor and pungency thresholds for odorants vary, with lower thresholds observed for odor detection (Cometto-Muniz & Cain, 1990). Pathways for the two nerves differ, where olfactory projections are primarily ipsilateral, and trigeminal projections are predominantly contralateral (Brodal, 1981; Kobal & Hummel, 1992). Due to differences in the projection pathways, trigeminal components of stimuli were of concern in the current study, since odorants were presented monorhinically, and laterality was an important issue. Thus, it was important to minimize stimulation of the trigeminal nerve as much as possible. Pilot work was originally done on the larger set of odorants described in Madigan et al. (1994) by using subjects with documented anosmia, as these individuals are unable to detect olfactory stimuli but have normal detection ability for the trigeminal nerve. Therefore, all odorants used in the current study were well below threshold for detection by the trigeminal nerve (see Appendix 1 for description of this pilot work).

All concentrations of odorants were made by volume in diethyl phthalate (DEP), an odorless solution, and were freshly prepared each week. The three pleasant odors were muguet (30%), jasmine (10%) and orange (30%); the unpleasant odorants were isovaleric acid (5%), thiophene (1%), and butyric acid (30%). Muguet (lily-of-the-valley) and jasmine are floral scents, whereas orange is a citrus scent. Isovaleric acid has been described as smelling like rancid butter or sweat, thiophene like rotten eggs, and butyric acid like strong cheese or vomit (see e.g., Gilbert & Greenberg, 1992). As facial expressions to odorants appear to be

difficult to elicit spontaneously (Gilbert, Fridlund & Sabatini, 1987), stronger concentrations of two of the unpleasant odorants were used for one of the experimental conditions. These highly unpleasant odorants consisted of thiophene (30%) and isovaleric acid (30%). All odorants except orange and thiophene were obtained from International Flavors and Fragrances. Thiophene was obtained from Fisher Scientific, and orange was diluted from McCormick's pure orange extract.

Scale Used for Intensity Ratings. A 21-point scale was used to determine intensity ratings for screening and experimental measures. Originally, this scale indicated only intensity, and ranged from 1 to 100 with increments of 5, and with 50 located in the middle of the scale. The scale was centered and arranged vertically on an 8-1/2" X 11" piece of paper, and was 10" in height. Five verbal labels were provided to the right of five of the numbers, to serve as reference points, where "1" indicated "slightly pleasant/unpleasant", "25" indicated "somewhat pleasant/unpleasant", "50" indicated "moderately pleasant/unpleasant", "75" indicated "very pleasant/unpleasant" and "100" indicated "extremely pleasant/unpleasant". The use of the scale was explained to the subjects. Subjects were also encouraged to use the full range of the scale, and not to limit responses to the numbers next to the verbal labels provided.

Some of the patients had difficulty in understanding how to use the original scale for intensity without reference to valence. For example, it was noted that they associated the lower part of the scale to unpleasant ratings, and the upper part to pleasant ratings. In these cases, these subjects were again instructed on how to use the scale. Seven subjects (2 RHDs, 2 LHDs, 3 NCs) used this original scale. However, because of the patients' difficulty in using this

original scale, the scale was modified to indicate intensity separately for both positive and negative hedonic valence.

The modified scale was a 21-point scale, ranging from + 10 to - 10, with intervals of 1 marked at each point on the scale; directly in the middle of the scale was 0. The scale was arranged vertically (10" in height) and centered on an 8-1/2" X 11" paper, to minimize any bias effects in individuals with a left visuospatial neglect. In addition, a dark black line was drawn to the left of the scale, to serve as an anchor point for individuals with this deficit. Five labels were also written to the right of the scale, next to one of five numbers, to provide points of reference. These labels were indicated as follows: "extremely pleasant" (+ 10), "moderately pleasant" (+ 5), "neither" (0), "moderately unpleasant" (-5), and "extremely unpleasant" (-10).

Since intensity ratings for seven subjects were made using the original scale, with points ranging from 1 to 100, these data were divided by 10, to fit the revised scale, which ranged from 1 to 10. As the original scale was unipolar, and the revised scale was bipolar, the absolute value was computed and used for ratings from the revised scale, so that all intensity ratings to be analyzed in the same manner.

Procedures

Screening Measures. To ensure that subjects understood the experimental task instructions, various measures were used or created to assess the participant's general cognitive abilities. These measures were also administered to exclude participants with dementia, severe comprehension difficulties, or anosmia. Standardized measures included: (1) Attention and

Memory Scales from the Dementia Rating Scale (DRS) (Mattis, 1988), to screen for attentional and memory difficulties; (2) Commands and Reading Sentences and Paragraphs subtests from the Boston Diagnostic Aphasia Examination (BDAE) (Goodglass & Kaplan, 1983), to ensure subjects could comprehend task demands; (3) Information (for RHDs and NCs) and Block Design (LHDs and NCs) subtests from the Wechsler Adult Intelligence Scale - Revised (WAIS-R) (Wechsler, 1981), as a general measure of the level of intellectual functioning; and (4) the Smell Identification Test (SIT), to assess general olfactory abilities (Sensonics, Inc.).

Two other measures were created to assess subjects' ability to make valence and intensity judgments on the odorants used in the experiment. For the task assessing valence, subjects were required to correctly indicate the valence (i.e., pleasant or unpleasant) of four emotionally-toned words ("good", "bad", "wonderful", and "terrible"). Each word was 1/4" in height and was centered on a 4" X 6" index card. Presentation of the four stimulus words was randomized across subjects. Subjects could either indicate the word was pleasant, unpleasant, or neither, or they could point to one of three schematic drawings of faces on a response card. The response card consisted of three words presented one above the other on an 8-1/2" X 14" piece of paper. A schematic drawing of a face was placed above each word (i.e., "pleasant"/extremely happy, "neutral"/neutral expression, "unpleasant"/extremely sad).

For judgments of emotional intensity, subjects were required to correctly order the intensity of the four emotionally-toned words (RHDs and NCs) or schematic drawings of faces (LHDs). The four words were the same as those used in the valence task; four faces were

shown to indicate extremely sad, sad, happy, extremely happy. Faces were 5-1/2" in height and 4-3/4" in width, and each was centered on an 8-1/2" X 11" piece of paper. Each pair of valenced stimuli (e.g., happy and extremely happy; sad and extremely sad) was presented to the subject. Presentation of stimulus pairs was counterbalanced across subjects. The subject was asked to rate the intensity of each stimuli separately on the previously described 21-point scale.

Criterion Performance for Screening Measures: For the DRS and BDAE measures, subjects who performed generally below two standard deviations below the mean in comparison to performance of healthy subjects (as provided in the test manuals) were excluded from participation. For the WAIS-R subtests, performance was required to be at least within the normal range (i.e., an age scaled score of 7 or higher). For normal controls, this criterion was applied to the average of the two age-corrected scaled scores. As odorants were presented to each nostril separately, olfactory performance for each nostril was assessed using the SIT, which uses a four-item, recognition format for odor identification. As the SIT consists of a total of 40 items, 20 items were presented to each nostril. Items were presented in four blocks of 5 trials each, to each nostril. A cotton ball was used to plug the untested nostril. Order of nostril presentation was counterbalanced across subjects in each group. Instructions were read to each subject, as indicated in the test manual. Odorants for each trial of the SIT were released by the examiner by scratching the label's surface with a pencil. Alternatives for each trial were shown and read to each subject, and choices recorded.

To ensure that subjects' olfactory abilities were adequate for study participation, subjects were required to correctly identify 10 of the 20 items for each nostril, as scores below

20 are indicative of probable anosmia when all 40 items are administered (Doty, 1983). However, a score of 10 out of 20 is well above chance levels (5 out of 20) of performance. As identification of odorants is a cognitively complex task in comparison to tasks requiring one to detect an odor or to make a hedonic evaluation (Richardson & Zucco, 1989), it was desirable to distinguish subjects who had difficulty identifying odors from those who were truly anosmic. If a subject's score for identifying odors for either nostril was below 10 correct, an odorant detection task was constructed (described below). Therefore, subjects correctly identifying fewer than 10 of the 20 items could participate in the study if they met criterion for the odorant detection task.

For the odorant detection task, subjects were blindfolded, and the first six odorants that the subject failed to identify from the SIT were presented. Each of the 6 odorants was presented in one of six trials consisting of the odor and a blank (i.e., a forced choice procedure). Order of items (i.e., blank versus odorant) in each trial was randomized. Subjects were asked to indicate which of the two items smelled stronger. In order to be included in the current study, the subject was required to correctly detect the odorant in five of the six trials, indicating performance was better than chance ($p < .05$) as determined by the binomial test.

The screening tasks were presented in the following fixed order to all subjects: Attention and Memory scales from the DRS; Commands and Reading Sentences and Paragraphs subtests from the BDAE; subtests from the WAIS-R; task assessing judgment of valence; task assessing intensity judgments; SIT; and if necessary, the six-item odor detection task. Task order was organized by: (1) standardized tasks assessing cognitive abilities; and (2)

tasks assessing hedonic judgments and olfactory abilities needed to complete the experiment. The tasks were then ordered from the least to the most demanding, to help place the subjects at ease and minimize anxiety.

Experimental Conditions. As facial expressions and experiential ratings were of interest in this study, several conditions were carried out to examine these affective components. Since facial displays are not frequently elicited to olfactory stimuli (e.g., Gilbert et al., 1987), spontaneous and prompted facial displays were examined in three conditions. Elicitation of spontaneous displays was modeled after Kraut's (1982) experiment. Subjective experience was examined in two different conditions: (1) to examine valence and intensity judgments; and (2) to explore preference between pleasant and unpleasant odorants using a forced choice procedure. Thus, the experiment consisted of five different conditions: Condition 1 - spontaneous facial expressions to odorants; Condition 2 - posed facial expressions to odorants; Condition 3 - subjective ratings of odorants; Condition 4 - choice preferences between pleasant vs unpleasant odors; Condition 5 - spontaneous facial expressions to highly unpleasant odorants. Detailed instructions given in each condition are provided in Appendix 2.

For Condition 1, subjects were merely told that this part of the study was to allow them to become familiar with the odorants and the method of presentation during the experiment; no mention was made of facial expression. For Condition 2, subjects were asked to "experience the odor as fully as you can, and then to show on your face how the odor makes you feel". Subjects were instructed that facial expression was important in this part of the study, and

several instructions were given (e.g., opening and closing the mouth, moving cheeks up and down) prior to administering odorant trials in order to exercise the subject's facial muscles. Subjects were asked not to make the expression until the command "Ready, go" was given, and then to hold the pose for several seconds.

In order to examine subjective ratings (Condition 3), the valence response card and intensity scale previously described were used to examine olfactory hedonic judgments. Subjects were instructed to make a judgment regarding perceived valence (i.e., pleasant, unpleasant, neither) of the odor. If the subject found the odorant to be pleasant or unpleasant, the subject was then instructed to determine hedonic intensity by pointing and calling off the number on the scale. The experimenter prompted the subject so that valence and intensity judgments were made independently, as some subjects would attempt to indicate valence and intensity judgments together on the intensity scale. Therefore, after each odorant trial, subjects were asked, "Is the odor pleasant, unpleasant or neither?" and then asked to indicate hedonic intensity.

For Condition 4, three pairs (each consisting of a pleasant and an unpleasant odorant) were given to the subject, and subjects were instructed to choose one odorant from each pair that they would prefer to smell for 30 seconds later on in the study. Subjects were given as much time as needed to choose the odorant.

For Condition 5, the two highly unpleasant odorants, as well as two of the pleasant odorants, were given to examine spontaneous facial expressions. Subjects were instructed that they would be asked some questions about the odorants after all were presented in an attempt

to minimize the experimenter's interest in facial expression. Subjects were told that as some individuals find these odors very unpleasant, they were given the option to not participate in this part of the study.

Presentation of Odorants. As facial expressions to odorants were of interest in this study, the odorants needed to be presented in a manner which would maximize visibility of facial displays. Methods using sniff bottles or olfactometers were not desirable, as such procedures block the lower part of the face from view (Cain, Cometto-Muniz and de Wijk, 1992; Doty, 1991). Therefore, each odorant was presented to the subject via a fragrance sniff strip (Orlandi Division, Jefferson Smurfit Corporation, Farmingdale, NY), which was horizontally placed with the broad side up between the subject's nose and upper lip for each trial. Fragrance sniff strips were dipped into each odorant 1 to 4 hours before the testing session. Separate sniff strips for each odorant were prepared for each of the 5 conditions, so that each odorant strip was used only twice.

The experimental session was conducted in a well-ventilated room equipped with a fan, in order to exhaust odorants from the testing room. In addition, each sniff strip was capped into a 18 mm X 150 mm glass test tube (Baxter Scientific) when not in use, in order to prevent diffusion of the odors into the testing environment.

For Conditions 1 through 3, and for Condition 5, subjects were instructed to take two sharp sniffs of each odorant. Subjects were asked not to talk while the odorants were being presented, as well as while they (the subjects) were posing expressions for Condition 2. The time interval between odorant trials was approximately 10 to 15 seconds. A Panasonic

videocamera was used to record the experimental session, and all subjects were aware that they were being videotaped. The videocamera was mounted on a tripod and placed in front of the subject at a distance of 5 to 7 feet, with the lens at the subject's eye level. Subjects were instructed to look straight ahead while sniffing the odors and while posing facial expressions.

All odorants were presented monorhinically, by plugging the untested nostril with a cotton ball. Thus, each odorant was presented twice during each condition, once to the right nostril, and once to the left nostril. Fragrance sniff strips were presented to the subject by the examiner, who stood behind the seated subject and off to one side. For each nostril, three of the six odorant trials were presented to the left side, and the other three to the right side. Order of nostril and side of presentation was counterbalanced across subjects. The six odorant presentations for each nostril were randomized for all conditions.

Control Measures. As group differences in facial displays may be due to differences in non-emotional facial movement, several control measures were employed to determine extent of facial paralysis and buccofacial apraxia, modeled after methods developed by Borod and her colleagues (Borod et al., 1986; Borod et al. 1987; Borod et al., 1988). In addition, posed emotional expressions were also examined, in order to better interpret facial displays elicited to odorants. Including such measures would help determine if differences in facial displays were due to a subject's ability to make emotional facial conditions in general, or to differences in displays elicited to the hedonic stimuli per se. Scoring of this information is discussed below.

To examine facial paralysis in the resting face, subjects were asked to look straight ahead at the camera for 30 seconds. Buccofacial apraxia was assessed by asking subjects to

perform six movements: sniff a flower, blow out a match, puff out their cheeks, lick their lips from side to side, suck through a straw and cough (Albert, Goodglass, Helm, Rubens, & Alexander, 1981). If a subject had difficulty performing the tasks to command, they were given a trial where they imitated the examiner, and\or where they used real objects (i.e., sucking a straw, sniffing a flower, and blowing out a match).

Finally, subjects' ability to pose hedonic and emotional facial expression was assessed by asking them to pose eight different hedonic and emotional expressions to command (i.e., pleasantness, unpleasantness, happiness, sadness, disgust, anger, fear, and surprise). This task was similar to that used by Borod and her colleagues (Borod et al., 1986; Borod et al., 1988; Kent et al., 1988). Subjects were given two trials to perform each expression, the first consisting of a practice trial. The practice trial was given to ensure that subjects understood the task and to facilitate a response, and thus subjects were given an example of the particular emotion. For instance, for pleasantness, subjects were instructed to look pleasant "as if you experienced something very pleasant or something that made you feel very good", and for disgust, they were instructed to look disgusted "as if you saw some rotten food and were very disgusted". A test trial was subsequently administered after the practice trial, where subjects were asked to pose the expression to the command "Ready, go". Subjects were instructed not to talk during the trials, and to hold the pose for several seconds. Subjects were asked to pose either the pleasant or unpleasant expression first, in order to assess the subject's notion of the pleasant/unpleasant expressions without the subject being influenced by experience in posing the six discrete emotional expressions. The order of the other six emotions was then

randomized between subjects.

Rating of Facial Expressions and Avoidant/Withdrawal Responses to Odors

Raters. Seven right-handed women served as raters to evaluate the facial displays and responses to odors. All raters were naive to the hypotheses being tested. Women were chosen to evaluate affective responses, as several studies suggest that women are better perceivers of emotion (e.g., Duda & Brown, 1985; Hall, 1978; LaFrance & Banaji, 1992). The raters were college students who were paid for their time. The average age of the raters was 23.9 years (sd = 6.3; range = 19 to 37 years), and average level of education was 14.3 years (sd = 1.0; range = 13 to 16 years).

Rating Procedures. Separate training sessions were conducted for the spontaneous and prompted expression conditions. For the spontaneous expression conditions (Conditions 1 and 5), raters were trained by the investigator during one four-hour session. Initial inter-rater reliability was determined, and then raters proceeded to evaluate the spontaneous expressions, first viewing all trials from Condition 1, then viewing the trials from Condition 5. After completion of these ratings, raters were trained during one two-hour session to evaluate the data from the prompted expression condition (Condition 2). As before, initial inter-rater reliability was determined, prior to raters evaluating the prompted expressions. Each rating session lasted approximately 3 hours. A total of 24 hours was needed to train the judges and to complete ratings for all expression data from the study.

The raters were told that the study was examining people's responses to odors, and that the subjects smelled a variety of odors differing in intensity and pleasantness. They were informed that subjects' nostrils were blocked, as the researcher wanted to control for nostril dominance, or the cyclical nature of nasal patency. No details were given regarding subject characteristics and diagnoses, and/or places where testing occurred. Instructions for making the ratings was given verbally and in writing. Verbal instructions and training procedures for rating the spontaneous and prompted expressions are provided in Appendices 3 and 4, respectively.

Judgments for each trial were recorded on a separate 8-1/2" X 5" rating sheet. Raters viewed each trial for approximately 10 seconds, beginning with the subject's first sniff, with a 10 second intertrial interval consisting of blank tape. Initial piloting of these procedures indicated that this was sufficient time for the raters to complete the ratings, turn the page and to wait for the next trial. All trials were viewed only once by the raters, and no review of any trial was permitted. Raters were instructed to indicate "cannot judge" for any rating they felt they were unable to make.

Response trials were viewed on one of two 20-inch monochrome television monitors, which were placed approximately 6 feet front and center of the group of raters. One monitor displayed the faces in the original orientation, and the other monitor was modified to present the displays in the mirror-reversed orientation. This was to control for any perceiver bias effects (discussed below). The sound on the monitor was turned off during the rating sessions so that evaluations were made solely on the basis of facial

expressions and avoidant responses.

Rating Measures. For spontaneous expressions, raters were asked to make 3 ratings for each trial: **hedonic quality, hedonic intensity**, and **presence of avoidant responses.** For prompted expressions, raters were asked to make two ratings for each trial: **hedonic quality** and **hedonic intensity. Hedonic quality** referred to whether the subject was smelling a pleasant odor, an unpleasant odor, or an odor which the subject found neither pleasant nor unpleasant. Judgments of pleasantness and unpleasantness were based on the subject's facial expression, using descriptions provided by previous investigators (Kniep et al., 1931; Steiner, 1974, 1977, 1979). In addition, judgments of unpleasantness could also be determined by presence of an avoidant response (described shortly).

If the rater determined that an odor was pleasant or unpleasant, she was asked to rate **hedonic intensity**, or how pleasant or unpleasant the subject found the odor, by using the 21-point rating scale. As the focus of the study was on facial expressions, hedonic intensity was determined by the degree or extent of the musculature involvement on the face. Therefore, for trials judged to be pleasant, hedonic intensity ratings ranged from +1 to +10. However, ratings of unpleasantness were based both on facial expressions and/or presence of an avoidant response. If judgments of hedonic quality were based primarily on the latter response, raters were instructed that there may or may not be any change in the contraction of the facial muscles. During the initial training, raters were shown examples to illustrate this point. Therefore, hedonic intensity ratings for trials judged to

be unpleasant ranged from 0 to -10, with 0 indicating no change in the contraction of the muscles on the face.

For spontaneous facial expressions (Conditions 1 and 5), subjects' responses were also examined for the **presence of avoidant/withdrawal responses.** Although it would have been ideal to also note presence of approach responses, such as leaning forward to smell the odor, the methodology used in the current study did not permit the examination of such behaviors. For example, subjects were instructed to take just two sniffs of the odorant. On the other hand, presence of avoidant/withdrawal responses were easily detected in the current study, as head movements were not restrained in any way. Avoidant/withdrawal responses in the current study were determined either by head movements away from the odor (i.e., turning head from side to side, jerking head up and back away from the odorant strip), or by an exaggerated blinking response. Verbal descriptions of such responses are provided in Appendix 3. Raters were merely asked to note the occurrence of such displays during any given trial.

Preparation of the Expression Data for Ratings. Facial expressions were examined in 3 of the 5 experimental conditions. In order to maximize any potential group and valence differences in facial displays, two factors were taken into account when preparing the expression data for viewing by the raters.

First, frequency and intensity of facial displays were expected to differ across the three conditions. For instance, fewer expressions were elicited for the spontaneous expression conditions (Conditions 1 and 5) than for Condition 2 (prompted facial

expressions). It was also postulated that expressions to highly unpleasant odors (Ccondition 5) would be more intense than to odorants presented in Condition 1. Since facial displays were expected to differ between the conditions, it was desirable to minimize any judgment biases on the part of the raters, which could be created or exaggerated merely by how the facial displays were presented.

Second, preliminary analyses on subjective hedonic ratings (Condition 3) suggested that there were group differences in hedonic ratings as a function of the valence of the odor (i.e., pleasant vs. unpleasant) (Madigan, Borod, Ehrlichman, & Tweedy, 1995). As valence effects within subject groups were of interest, it was desirable to present the facial displays to the raters in a manner which would help raters detect such an effect. Therefore, raters would need to be able to compare an individual's expression to different odorants, rather than comparing the expressions to different subjects.

In order to take both factors into account, videotaped facial expressions were randomized and presented in the following manner. The three conditions were presented to raters in terms of displays thought to elicit the least to most frequent and/or intense facial displays. Thus, all trials of Condition 1 (spontaneous expressions) were presented before Condition 5 (spontaneous expressions to highly unpleasant odors), which were in turn were rated before displays elicited in Condition 2 (prompted expressions). As order of nostril presentation for the six odorants was counterbalanced across subjects, each condition was broken into two blocks based on nostril presentation (right versus left). Thus, for Conditions 1 and 2, raters viewed a subject's responses across one of two blocks

of six trials, with each block consisting of three pleasant and three unpleasant odors, prior to being presented with another subject's data. Data for each condition were randomized by subject and then by nostril, and each combination consisted of a block of 6 trials (see Table 4 illustrating the design used in presenting data to the raters). Therefore, for Conditions 1 and 2, there was a total of 116 blocks presented (58 subjects X 2 blocks). The restriction on this randomization procedure was that data from one block from each subject would appear in the first 58 blocks. For Conditions 1 and 2, a total of 693 trials per condition was presented, as three of the trials were accidentally erased during editing.

For Condition 5, only 41 subjects completed the condition, as subjects were given the option not to participate in this condition. A total of 82 blocks were presented to the raters (41 subjects X 2 blocks). For Condition 5, a block consisted of 4 trials (2 pleasant, 2 highly unpleasant odors), so that a total of 324 trials were rated. Altogether, each rater evaluated 1,017 trials of facial responses to odorants.

As a left visual-field perceiver bias has been observed in free field viewing of facial expressions (Borod et al., 1989, 1990; Jaeger et al., 1987; Levine & Levy, 1986; Levy et al., 1983; Moreno et al., 1990; Sackeim & Grega, 1987), facial displays were viewed either in original or mirror reversed orientation. This effect, in addition to the presence of facial hemiparesis, could potentially confound the results of the present study. For example if the left hemispace perceiver bias was operative, than facial responses of individuals with right facial paresis (e.g., LHDs) may be evaluated as being less expressive. In order to minimize this potentially confounding effect, orientation of facial displays was

counterbalanced within the three subject groups, with the expressions of half the subjects in each group being viewed in original orientation, and the other half being viewed in the mirror reversed orientation. This part of the design is also illustrated in Table 4.

Table 4. Illustration of Design Used When Creating Rating Tapes and When Presenting Data to the Raters.

Trial number*	Subject number	Group	Nostril presentation	Odorant presentation**	Orientation of displays
1-6	1	RHD	Right	3 p /3 u	Original
7-12	2	LHD	Left	3 p /3 u	Original
13-18	3	RHD	Right	3 p /3 u	Original
19-24	4	NC	Right	3 p /3 u	Reversed
25-30	5	LHD	Left	3 p /3 u	Reversed
31-36	6	NC	Left	3 p /3 u	Reversed
37-42	4	NC	Left	3 p /3 u	Reversed
43-48	6	NC	Right	3 p /3 u	Reversed
49-54	5	LHD	Right	3 p /3 u	Reversed
55-60	1	RHD	Left	3 p /3 u	Original
61-66	3	RHD	Left	3 p /3 u	Original
67-72	2	LHD	Right	3 p /3 u	Original

*Trial number depicts expression trials rated by judges.
** Odorant presentations for each subject are completely randomized (p = pleasant, u = unpleasant).

Training Procedures. Procedures for training the raters for both spontaneous and prompted expressions were developed in Dr. Borod's laboratory, and based specifically on studies by Moreno (1987) and Kent et al. (1988). Raters were first trained to evaluate the spontaneous expressions, and after all ratings were completed for Conditions 1 and 5, they were then trained to evaluate the expressions elicited in Condition 2. For each instruction session, training consisted of showing exemplars (12 examples for spontaneous expressions from Conditions 1 and 5; 9 examples for prompted expressions from

Condition 2) to illustrate expressions differing in hedonic quality and hedonic intensity (Conditions 1, 2 and 5), and presence of avoidant responses (Conditions 1 and 5 only). Detailed instructions and procedures given to raters are provided in Appendices 3 and 4. All seven raters were trained as a group during the training session.

After this phase, raters were then presented with different videotaped clips which were rated for each rating scale (e.g., hedonic category, hedonic intensity, presence of avoidant/withdrawal responses). For spontaneous expression conditions, 18 training examples were used, and for prompted expressions, 15 training examples were used. These responses were compared and discussed until at least partial agreement (5 out of 7 raters) was achieved with respect to making valence judgments and to noting avoidant responses for the majority of training trials. In addition, intensity ratings for responses judged to be pleasant or unpleasant were either in agreement or did not deviate by two points for the majority of training trials. The emphasis on maximizing agreement between the raters was critical in order to ensure high interrater reliability (assessed by Cronbach's alpha). Thus, raters were encouraged to discuss rating strategies, and problematic clips were reviewed by the raters to discuss as a group.

Exemplar and training examples consisted of facial expressions from several subjects (2 to 3 LHDs, 2 to 3 RHDs, 2 to 3 NCs) who were actual participants in the study. One to three expressions from each subject were selected to represent the various types of responses (i.e., 3 pleasant, 3 unpleasant, 3 neither, 3 avoidant responses) being examined, and facial displays for pleasant and unpleasant odors were matched for intensity

(i.e., 0, +/- 2, +/- 3 for spontaneous expressions; +/- 2, +/- 5, +/- 7, +/-9 for prompted expressions). The range for intensity was restricted for the spontaneous expression conditions, as there were few examples of high intensity, pleasant expressions in the data set.

Interrater reliability for both spontaneous and prompted expressions was determined by presenting six trials from 12 participants in the study, whose responses were not previously viewed by the raters (4 LHDs, 4 RHDs, 4 NCs). Thus, a total of 72 videotaped clips were shown to the raters for purposes of determining initial interrater reliability. Half of the displays were presented in the original and half in the reverse (i.e., mirror) orientation. Orientation of displays was counterbalanced between subjects within each group, so that half of the subjects were viewed in original orientation and half in mirror-reverse orientation. Intraclass correlations were completed to examine interrater reliability, with the goal of obtaining a Cronbach's alpha of .80. In addition, reliability was determined by eliminating each rater, to ascertain any idiosyncrasies in the ratings of an individual rater. If ratings from an individual rater were problematic, it was determined that results from that rater would not be used in data analyses.

Based on the ratings from the 72 trials, initial inter-rater reliability for the seven raters was determined by computing Cronbach's alpha. The alpha values for spontaneous expressions (Conditions 1 and 5) were .76 for hedonic quality, .89 for hedonic intensity and .94 for presence of an avoidance/withdrawal response. The alpha values for prompted expressions (Condition 2) were .97 for hedonic quality and .87 for hedonic

intensity. For both types of expressions, no judges' ratings were problematic, so it was determined that results from all raters would be used for analyses. Since agreement among the raters was high, the ratings for the seven judges were averaged for each trial in the data analysis.

Ratings of Posed Hedonic Facial Expressions and

Facial Expressions to Six Discrete Emotions

Raters. Judges consisted of 5 right-handed women. The mean age of the raters was 21.0 years (sd = 0.7; range = 20-22 years) and the average years of education was 14.8 (sd = 0.5; range = 14 to 15 years). As with all other tasks, raters were naive to the hypotheses being tested, as well as to the characteristics of the subjects.

Rating Procedures. Separate training sessions were conducted for posed hedonic expressions and posed expressions to six discrete emotions. For the task assessing posed hedonic facial expressions, raters were trained during two sessions, each lasting two hours. Two training sessions were needed, as it was determined that the raters were not following the guidelines established for judgments of intensity of facial expressions. Initial interrater reliability was determined on a subset of the data. After all ratings for posed hedonic expressions were completed, raters were then trained during two two-hour sessions to evaluate posed facial expressions to six discrete emotions. Initial interrater reliability was determined, prior to evaluating all response trials. Rating sessions lasted approximately two hours; a total of 12 hours was needed to train the raters and complete

all ratings.

For **posed hedonic facial expressions**, raters were instructed that the subjects were asked to imagine a hedonic state (i.e., pleasant, unpleasant, neither) and then to show on their face how they felt. For **posed facial expressions to six discrete emotions**, raters were informed that subjects were asked to imagine one of six emotions (i.e., happiness, sadness, anger, fear, disgust, surprise) and to express that emotion on their face. Although subjects were asked to produce each of the six emotions in different random orders, raters were deliberately misled to believe that a subject might have been asked to make an emotion repeatedly over several trials. This instruction was necessary in order to minimize any expectancy effect on the part of the raters, due to way in which the data was presented.

For both tasks, judgments for each trial were recorded on separate 8-1/2" X 5" rating sheets. Raters viewed each trial for approximately 5 seconds, beginning at the "Ready, go" prompt given to the subject. The inter-trial interval was 10 seconds, giving the raters time to record their judgments, to turn the page and to view the next trial. Review of any trial was not permitted.

As with the other tasks, expression trials were viewed on one of two 20-inch monochrome television monitors, one monitor presenting the image in the original, and the other in mirror-reversed. As for the control measures, orientation of a subject's data was held constant for all tasks, so that if the subject's data was presented in original orientation for the experimental tasks, it was likewise presented in original orientation for the posed

facial expression tasks.

Rating Measures. **Posed Hedonic Facial Expressions.** As this task was meant as a control task to better interpret findings for facial responses to odors, the instructions for this task were only modified slightly from those used for Condition 2 (prompted expressions to odors). For this control task, raters were asked to determine **hedonic quality** and **hedonic intensity** for each trial, and rating sheets were identical to those used for Condition 2.

Posed Facial Expressions to Six Discrete Emotions. This task was designed merely to examine a subject's general ability in posing emotional facial expressions. For each trial, the raters were asked to make three ratings: **category of the emotional facial expression, degree of confidence in their judgment of emotional category**, and **intensity of the facial expression.** For **emotional category**, raters were required to choose one of the six emotional categories (i.e., "happy", "sad", "fear", "disgust", "anger", "surprise"). As the raters' choices for a subject might have been influenced by previous judgments, choices for each emotional category were written on separate pieces of paper (8-1/2" X 4") to minimize this effect, and the words representing each category were presented in six different random orders across trials. Raters were also asked to rate their **degree of confidence** for their judgment of emotional category. This rating was meant to clarify any possible group differences in terms of accuracy of posing emotional expressions. For example, lower accuracy scores could result from either an inaccurate pose which was prototypical for a certain emotional category, or an inaccurate pose which

was not prototypical. Thus, it was expected that the more prototypical the expression, the higher the confidence rating. Confidence ratings were made on a 5-point Likert scale, with 1 indicating "Not at all confident", 2 "Somewhat confident", 3 "Moderately confident", 4 "Very confident", and 5 "Extremely confident". Raters were instructed that a rating of "1" would indicate their judgment of emotional category was a guess, whereas a rating of "5" meant that their judgment of emotional category was clearly not on of the other five emotional categories. Finally, raters were asked to determine the **intensity** of the emotional facial expression. Intensity was inferred by the degree of musculature involvement in the expression. These ratings were made on a 7-point Likert scale, ranging from "1" (Not at all intense) to "7" (Extremely intense). Raters were asked to rate the most intense expression viewed at any given point during the trial.

Preparation of the Data. Since ratings of the pleasant and unpleasant facial expressions may be difficult to distinguish from certain discrete emotions (e.g., happiness, sadness, disgust), the raters first viewed subjects' pleasant and unpleasant expressions prior to viewing expression to the six discrete emotions. With this restriction, videotaped clips were randomized across subjects. Since order of pleasant/unpleasant expressions and order of discrete emotions were randomized during task administration, data from an entire subject was presented to the raters. Thus, for pleasant and unpleasant expressions, the raters viewed both of these expressions from a single subject before viewing these two expressions from the next subject. Likewise, all six discrete emotional facial expressions from a single subject were viewed prior to trials from a subsequent subject. Raters viewed

only the test trials from each subject. All trials were viewed beginning at the "Ready, go" prompt. Each trial was shown for approximately 5 seconds. The 10 second inter-trial interval consisted of blank tape.

For the posed hedonic facial expressions task, a total of 116 trials was presented (58 subjects X 2 poses). For the posed facial expressions to six discrete emotions, a total of 343 trials were shown, with five trials lost due to recording difficulties (58 subjects X 6 poses = 348 - 5).

Training Procedures. The training procedures used were based on previous studies examining posed emotional expressions in brain-damaged subjects (see e.g., Kent et al., 1988; Moreno, 1987). For the task assessing facial expressions to six discrete emotions, verbal descriptions and photographs of protypical expressions were shown to the raters demonstrating differences in emotional category (examples from Ekman, 1975; Ekman & Friesen, 1975). For both posed facial expression tasks, photographs of facial expressions varying in intensity were presented, to demonstrate use of the intensity scale (Ekman & Friesen, 1975). Then, videotaped exemplars for each task were shown to the raters to demonstrate differences in hedonic quality and intensity, and in emotional category and intensity (9 exemplars for posed hedonic expressions, 13 exemplars for posed facial expressions to six discrete emotions) from 8 participants (3 LHDs, 1 to 3 RHDs, 2 to 4 NCs) .

To ensure high interrater reliability, training examples were then presented to the raters, where responses could be compared and discussed. For posed hedonic

expressions, 12 training examples from six participants (1 LHD, 2 RHDs, 3 NCs) were shown during initial training. As review of ratings made during initial interrater reliability indicated that intensity ratings across raters was not systematic and suggested that the raters were not following the guidelines established, an additional 10 training examples from 8 subjects (3 LHDs, 3 RHDs, 2 NCs) were presented and discussed as a group. For posed facial expressions to six discrete emotions, 19 training examples were presented from 7 participants (3 LHDs, 2 RHDs, 2 NCs), with 3 examples from each category, and with the expressions ranging in intensity (from 1 to 6).

For the training examples, it was desirable to have maximum agreement among the raters for judgments of hedonic quality, emotional category and intensity to ensure high interrater reliability. Therefore, for the majority of training trials, partial agreement (4 out of 5 raters) for judgments of hedonic quality and emotional category was desired. Intensity ratings for the majority of trials were in agreement or did not deviate by more than two points.

Inter-rater reliability was determined on data from a subset of the expression trials. For posed hedonic expressions, initially 24 trials were shown from 12 participants (3 LHDs, 3 RHDs, 3 NCs). Since additional training was needed due to problematic intensity ratings, initial interrater reliability was determined from 60 trials consisting of data from 30 participants (11 LHDs, 12 RHDs, 7 NCs). For the posed facial expressions to six discrete emotions, reliability was calculated from observations from 12 study participants (3 LHDs, 3 RHDs, 3 NCs), consisting of a total of 72 trials. As with the

other measures, part of the subjects' data was viewed in original orientation and part in reversed orientation. A Cronbach's alpha of at least .80 was desired. As before, it was determined that a rater's data would not be included in the data analysis if Cronbach's alpha was below .80.

For **posed hedonic expressions**, alpha levels were computed using 60 trials. For hedonic quality, the alpha level was .93 and for hedonic intensity, the alpha level was .86. For **posed facial expressions to six discrete emotions**, alpha levels determined using 72 trials were .89 for emotional category, .83 for confidence ratings, and .93 for emotional intensity. As with the other tasks, since inter-rater agreement was high, the ratings for the five judges were averaged for the data analysis.

Ratings of Buccofacial Apraxia and Facial Paralysis

Raters. These two control measures (assessment of buccofacial apraxia and facial paralysis) were presented to a separate group of four raters, consisting of right-handed women. Mean age of these raters was 20.3 years (sd = 1.5; range = 19 to 22 years), and mean education was 14.5 years (sd = 1.3; range = 13 to 16 years). The raters were naive to the hypotheses being tested as well as to the types of subjects being tested in the study.

Rating Procedures. Separate training sessions were conducted to assess buccofacial apraxia and facial paralysis. Training for each task took approximately 3 hours. The four judges first rated all trials from the buccofacial apraxia tasks, prior to receiving training and assessing facial paralysis. Following the training session for each

task, initial inter-rater reliability was determined on a subset (72 trials) of the actual data set. Rating sessions lasted approximately 2 hours. A total of 10 hours was needed to train and to complete all ratings for these two control measures.

For the **buccofacial apraxia tasks**, ratings for each task were made on separate 8-1/2" X 5" pieces of paper. The trial was viewed at the time the command was given to perform the task until the subject completed the movement. The inter-trial interval was 10 seconds, consisting of blank tape, to allow the raters time to complete the ratings, turn the page and wait for the next trial. For **facial paralysis**, ratings for each subject was made on two sheets of 8-1/2" X 11" pieces of paper. A videotaped still of the resting face was shown to the raters; raters were given 30 seconds to complete their ratings.

Response trials were viewed on one of two 20-inch monochrome television monitors, with the sound turned off. As for the experimental tasks, one of the monitors presented the image in the original orientation, whereas the other monitor presented the image in mirror-reverse. The orientation of displays for each subject was the identical for the experimental and control measures. That is, if the subject's data were viewed in the original orientation for the experimental measures, that subject's data for the control measures were also viewed in the original orientation.

Rating Measures. **Buccofacial Apraxia.** Assessment of buccofacial apraxia was based on procedures developed by Borod et al. (1986, 1987, 1988), where **accuracy** of performing movements and **ease of execution of movements** were rated. **Accuracy (or correctness)** of movement was based on location, shape and direction of movement.

Level of accuracy was indicated on a two-point binary scale, with a score of "0", indicating the movement was performed incorrectly or inaccurately, and a "1" indicating the movement was performed correctly or accurately. To receive a score of "1" on accuracy, the rater must determine that the location, shape, and direction of movement was correct. Examples of incorrect movements described and shown to the raters for each movement were as follows: (1) sniffing a flower = no sniffing response observed; (2) blowing out a match = the lips not being pursed, or no movement indicating an exhalation; (3) puffing out the cheeks = moving the mouth out and back to make the cheeks appear wider; (4) licking the lips from side to side = licking the lips on the inside rather than the outside of the mouth, or moving the lips themselves from side to side; (5) sucking through a straw = the lips not being pursed, or no movement sucking in; (6) coughing = no actual coughing response observed.

Ability or ease of execution of movements was scored on a 3-point scale (i.e., "1" = poorly or clumsily executed; "2" = slightly clumsy, and "3" = well-executed). Raters were instructed that a well-executed movement was facile, and performed quickly and smoothly. Clumsily executed movements were described as taking longer to complete, where the subject performed the movement hesitantly, and where multiple attempts were made to perform the movement.

Facial Paralysis. The procedure used to measure the extent of upper and lower facial paralysis of the resting face was based on Borod et al.'s studies (Borod et al., 1986, 1988). Six different parameters were assessed: (1) appearance of wrinkles on the

forehead; (2) position of the eyebrow; (3) eyelid size; (4) depth of nasolabial fold; (5) corner of the mouth position; and (6) direction to which the middle of the mouth is pointing. Thus, three parameters measured upper facial paresis and three measured lower facial paresis. Each feature was rated on a 5-point scale, ranging from "-2" to "+2", with "0" directly in the middle of the scale. Negative numbers ("-1" or "-2") indicated the feature was more prominent or noticeable on the left hemiface, whereas positive numbers ("+1" or "+2") indicated the feature was more prominent or noticeable on the right hemiface. Raters were instructed that a "+2" or "-2" indicated that there was a large and noticeable difference in the feature when comparing the right and left sides of the face, whereas a "+1" or "-1" indicated a slight but noticeable difference. A "0" indicated that the feature appeared to be equivalent on the right and left sides of the face. These ratings were converted (described under Scoring section) to indicate **direction** and **extent of the facial paralysis.**

Preparation of the Data. For the **buccofacial apraxia** task, trials were edited at the time the command was given to perform the task until the subject completed the movement. The six trials from each subject were viewed consecutively by the raters. Prior to viewing each trial, raters were informed of the instructed movement. The blocks of data was randomized across subjects. The trials were previewed by the examiner and another judge to ensure that some type of response was made for each movement trial. Based on this initial preview, 3 of the 348 trials were not presented to the raters, as no response was discernible by either judge in the initial preview. Therefore, a total of 345

trials was presented to the raters.

For the **facial paralysis task**, a videotaped still of the resting face was presented to the raters. The face remained in view for a duration of 30 seconds, giving the raters ample time to complete their judgments for the six features. Presentation of the data was randomized across subjects. A total of 348 trials were evaluated by the raters.

Training Procedures. The procedures used were similar to those described for the expression data in response to odors. Raters were first trained to evaluate the buccofacial apraxia tasks, and after all ratings were completed, they were then trained to evaluate facial paralysis. During the training session for each task, the scales and guidelines to be used were explained to the raters, and exemplars (12 for buccofacial apraxia, 18 for facial paralysis) were shown demonstrating the various types of responses or aspects of features being examined.

The raters were then given training examples (18 training examples for both buccofacial apraxia and facial paralysis) to rate. These ratings were first made independently, and then compared and discussed as a group. As before, ratings were compared and discussed until at least partial agreement (3 out of 4 raters) was achieved on the majority of the training examples for each scale, to ensure high inter-rater reliability. Raters were therefore encouraged to discuss their strategies when making their ratings for each trial.

For **buccofacial apraxia**, exemplars consisted of videotaped clips from 6 subjects (3 LHDs, 1 RHD, 2 NCs) who were actual participants in the study. For each of the six

movement tasks, two examples were shown demonstrating a correct and an incorrect performance. These examples also varied in terms of execution, and were chosen to illustrate how ratings of correctness were independent of ratings of execution. The 18 training examples were obtained from 8 subjects (4 LHDs, 2 RHDs, 2 NCs), and varied in terms of accuracy and execution.

For **facial paralysis**, exemplars consisted of a viewing of the resting face consisting of videotaped stills from three subjects (1 RHD, 1 LHD, 1 NC). Exemplar ratings were provided by the examiner for the six features for each subject. Exemplars were chosen to demonstrate large (i.e., "+2", "-2") and slight (i.e., "+1", "-1") differences for different features. Raters were then presented with videotaped stills from three other subjects (1 RHD, 1 LHD, 1 NC) to rate and then discuss.

Initial interrater reliability was determined for each task by having raters view data from twelve other subjects (4 RHDs, 4 LHDs, 4 NCs) for each of the six buccofacial tasks and the six facial parameters, for a total of 72 observations. The raters viewed half of the trials either in the original or mirror-reversed orientation. As before, intraclass correlations were used to determine reliability; for each measure, a Cronbach's alpha of .80 was desired.

For the **buccofacial apraxia** task, alpha levels for accuracy and ease of execution across the 72 trials were .83 and .80, respectively. The alpha level based on a subset of the data (72 trials) for the **facial paralysis** rating was .81. All alpha levels were considered to be sufficiently high to average across the four raters in the data analyses.

Scoring

Measures Used for Responses to Odors. Both experiential and facial expression data were recoded to represent three dependent measures: presence of a hedonic response (responsivity), accuracy, and intensity. In addition, conditions examining spontaneous facial expressions included a measure representing presence of an avoidant/withdrawal response. **Presence of a response (responsivity)** indicated the occurrence of a hedonic response, via a binary scale. A score of "1" was used to indicate a hedonic response (i.e, if the odorant trial was judged to be pleasant or unpleasant), and a score of "0" was used to indicate no hedonic response (i.e., if the trial was rated as neither pleasant or unpleasant). If a hedonic response was made, then an accuracy score for the odorant was determined. **Accuracy** indicated the agreement between the hedonic judgment made during the trial to the a priori classification of the odorant. Thus, a score of "1" was used to indicate agreement, with "0" indicating an inaccurate response (disagreement). **Intensity** ratings were completed only on trials where a hedonic (i.e., pleasant or unpleasant) response was made. These ratings were obtained by taking the absolute value of the intensity score made during the trial.

For the statistical analyses, a subject's rating of the odorant (Condition 3) was used for experiential trials, and the mean of the seven judges' ratings was used for each expression trial. For each of the three dependent measures (responsiveness, accuracy and intensity), four means were then calculated for each subject within each condition, denoting average scores to represent nostril and valence effects. The hedonic valence of

the odors was determined a priori, as previously described. For instance, means were calculated for the 3 pleasant odors and for the 3 unpleasant odors administered to the right nostril, as well as for the 3 pleasant and for the 3 unpleasant odors administered to the left nostril.

For Conditions 1 and 5 (spontaneous facial conditions), raters were also asked to note the **presence of withdrawal/avoidant responses**. Here, for each odorant trial, a binary score was used, with "1" indicating the presence of response and "0" indicating the absence of a response. The mean scores from the seven raters was calculated for each expression trial. Four mean scores were calculated for each subject across trials, based on the valence category and nostril presentation.

For the behavioral choice measure, a number between 0 and 3 was given to represent the number of pleasant odors chosen. Thus, each subject received a score between 0 and 3 on this measure.

Measures for Posed Hedonic Facial Expressions and Posed Facial Expressions to Six Discrete Emotions. Measures for **posed hedonic facial expressions** were the same as for the experimental tasks: presence of a hedonic response (responsivity), accuracy, and intensity. For each trial, a mean value was computed from the 5 judges' ratings. Therefore, for each dependent measure, two scores representing pleasant and unpleasant expression trials were calculated for each subject.

For **posed facial expressions to six discrete emotions,** accuracy, intensity and confidence rating scores were calculated for each subject. A binary scale was used to

represent accuracy ("1" = accurate; "0" = inaccurate). Again, for each trial, the mean from the 5 raters' judgments was computed. Three measures representing accuracy, intensity and confidence rating scores were obtained for each subject, by calculating the averaged ratings over the six expression trials.

Control Measures for Facial Expression. Each of the four control measures (e.g., buccofacial apraxia, facial paralysis, posed hedonic expressions, posed facial expressions to discrete emotions) was scored separately. For **buccofacial apraxia**, the mean of the four judges' ratings were used for each of the six movement trial. Subjects received separate apraxia scores (mean score calculated over the six movement trials) for accuracy and execution.

For **facial paralysis**, scores for direction of paralysis and extent of paralysis were recoded from original ratings for each feature. For direction, a 3-point scale was used, where a score of "-1" indicating right facial paralysis (or asymmetry), "+1" indicating left facial paralysis (or asymmetry) and "0" indicating the feature appeared equivalent on the left and right sides of the face. Extent of paralysis was determined by using the absolute value of the ratings. The mean of the four ratings for each feature (i.e., trial) was used in the data analysis. For direction and extent of paralysis, each subject received a score for the upper face (mean of three features) and a score for the lower face (mean of three features).

RESULTS

Findings for this study are divided into six major components. The specific analyses used for each component are discussed within each section. Results are considered significant at ($p \leq .05$), and trends ($p \leq .10$) are also discussed; these findings will be discussed as to whether or not they support the a priori hypotheses.

First, results from facial responses to odors and subjective ratings of odorants were analyzed, to determine whether the findings supported the right hemisphere or valence hypothesis. The facial expression conditions are reviewed first, examining first spontaneous and then prompted expressions to odors, using measures of responsivity, accuracy and intensity. Next, findings from the experiential conditions (i.e., subjective ratings and choice measures) are reported.

When relevant, findings from the experiment are discussed in terms of their relationship to pertinent control measures (e.g., overall olfactory identification performance, presence of buccofacial apraxia) which may influence the findings. For example, non-emotional facial movement factors may play a role in hedonic and emotional facial expression. For the sake of clarity, results analyzing group differences for these control measures (olfactory and cognitive performance, buccofacial apraxia, facial paralysis) and their relationship to experimental measures (i..e, correlational analyses) are discussed in Appendix 5. Thus, when significant group differences emerged for the control measures and when the control measures correlated significantly to experimental measures, the control task was used as a covariate. When the statistical findings were

altered when controlling for such effects, the experimental findings for the Analysis of Covariance (ANCOVA) are reported.

Second, in order to assist in the interpretation of the findings from the facial expression data from the experimental proper, several conditions were included to examine hedonic and emotional facial expressions without using olfactory stimuli. These conditions consist of posed hedonic expressions (produced without using odorants) and posed facial expressions to 6 discrete emotions. As before, when appropriate, control measures (e.g. presence of buccofacial apraxia) were used as covariates when reporting these results.

Third, intrahemispheric effects are explored for the expression and subjective rating (experiential) data from the experiment proper. Here, it was hypothesized that anterior brain regions were more involved in hedonic experience and expression. To address this issue, findings from a subset of RHD and LHD subjects who had lesions confined to posterior cortical regions were compared with RHD and LHD subjects having lesions encompassing both anterior and posterior cortical regions. In addition, since months post onset differed between the posterior only and anterior plus posterior groups, this variable was correlated to the experimental measures (see Appendix 5). When appropriate, it was used as a covariate in these analyses.

Fourth, presence of avoidance responses are analyzed to determine whether or not there is a right hemisphere dominance in avoidant/withdrawal responses. Avoidance responses were examined by the raters during the two spontaneous facial expression

conditions (Conditions 1 and 5). Intrahemispheric effects for this action tendency are also reported.

Fifth, the relationship between subjective ratings of hedonic intensity and judges' ratings of intensity of facial expressions is reported for both spontaneous and prompted expressions to odors. These analyses would indicate whether or not experiential and expression components were dissociable from one another within a particular subject group.

Sixth, the relationship of experimental measures within each condition was explored. These analyses may not only aid in the interpretation of the findings, but also indicate the coherence of the experimental measures for a particular group (i.e, LHDs, RHDs, NCs).

Right Hemisphere vs. Valence Hypotheses - Responses to Odor Presentation

Several mixed design, repeated measures ANOVAs were conducted to examine findings from each measure for the facial expression and experiential data. The between subject factors consisted of Group (LHDs, RHDs, NCs), and within subject factors consisted of Valence (pleasant odors, unpleasant odors) and Nostril (right, left). Newman-Keuls multiple comparison procedures were used when making all post-hoc comparisons. Table 5 reviews the parameters used for facial expression and subjective rating data, including the score ranges and description of each parameter.

Table 5. Parameters for Facial Expression Measures and Subjective Ratings to Odors with Score Ranges

Condition	Parameter	Score range	Parameter Description
Spontaneous Facial Expressions to Odors (Conditions 1 and 5)	Responsivity*	0-1	Whether or not the hedonic quality of the response was judged to be pleasant/unpleasant vs. neither
	Accuracy**	0-1	Whether or not the judgment of hedonic quality agreed with the a priori classification of the odor
	Intensity***	0-10	Degree of musculature involvement on the face
Prompted Facial Expressions to Odors (Condition 2)	Responsivity*	0-1	Whether or not the hedonic quality of the response was judged to be pleasant/unpleasant vs. neither
	Accuracy**	0-1	Whether or not the judgment of hedonic quality agreed with the a priori classification of the odor
	Intensity***	0-10	Degree of musculature involvement on the face
Subjective Ratings to Odors (Condition 3)	Responsivity*	0-1	Whether or not subject found the hedonic quality of odor to be pleasant/unpleasant vs. neither
	Accuracy**	0-1	Whether or not the subject's rating of hedonic quality agreed with the a priori classification of the odor
	Intensity***	1-10	How pleasant/unpleasant the subject found the odor
Behavioral Choice Measures (Condition 4)		0-3	Number of pleasant odors chosen using a forced choice procedure

* From neither pleasant/unpleasant (low) to pleasant/unpleasant (high).
**From inaccurate (low) to accurate (high).
*** Absolute value for scale (score range: -10 to +10); from none/minimal (low) to maximal (high).

Given the three factors (Group, Valence, Nostril) examined, Table 6 shows the pattern of findings expected which would support each hypothesis if significant Group, Group by Valence, Group by Nostril, or Group by Valence by Nostril interactions emerged. Also indicated is the pattern of group differences expected for the post-hoc comparisons.

Table 6. Statistical Effects Expected to Emerge Which Would Support Either the Right Hemisphere or Valence Hypotheses

Source (if significant)	Right Hemisphere Hypothesis	Valence Hypothesis
Group (G)	RHD < LHD = NC	
G x Valence (V)		
Pleasant		LHD < RHD = NC
Unpleasant		RHD < LHD = NC
G x Nostril (N)		
Right	RHD < LHD = NC	
Left	RHD = LHD = NC	
G x V x N		
Right pleasant		
Right unpleasant		RHD < LHD = NC
Left pleasant		LHD < RHD = NC
Left unpleasant		

Spontaneous Expressions to Odors. The raters did not judge the spontaneous facial expressions in response to odors to be significantly different between the LHD, RHD, and normal control subjects for any measured parameter. Thus, there were no group differences in the ability to respond hedonically to the odors, in the accuracy or appropriateness of the response, or in intensity of facial expressions. Table 7 reports the findings from the ANOVA results from Condition 1, and mean and standard deviations for the main effects and interaction effects with Group are reported in Table 8. Likewise, there were no significant group differences for any of these measures when highly unpleasant odorants were used to elicit spontaneous expressions (Condition 5). Tables 9 and 10 show results from the ANOVA and means and standard deviations for the main effects and interaction effects with Group for this analysis.

Table 7. Results of ANOVAs for Spontaneous Expressions to Odors (Condition 1) for Measures of Responsivity, Accuracy and Intensity

	Responsivity			Accuracy			Intensity		
Source	df	F	p	df	F	p	df	F	p
Between Subjects									
Group (G)	2	1.71	.19	2	.98	.38	2	.86	.43
S within-group error	55	(.15)		55	(.04)		55	(.58)	
Within Subjects									
Valence (V)	1	14.32	.000	1	78.16	.000	1	6.96	.01
G x V	2	.77	.49	2	.93	.40	2	1.66	.20
V x S within-group error	55	(.02)		55	(.15)		55	(.28)	
Within Subjects									
Nostril (N)	1	1.96	.17	1	.03	.87	1	1.01	.32
G x N	2	.59	.56	2	1.74	.19	2	1.33	.27
N x S within-group error	55	(.02)		55	(.04)		55	(.19)	
Within Subjects									
V x N	1	.62	.43	1	.08	.78	1	.20	.66
G x V x N	2	.77	.47	2	2.47	.09	2	1.43	.25
V x N x S within-group error	55	(.02)		55	(.04)		55	(.13)	

Note: Values enclosed in parentheses represent mean square errors.

Table 8. Means of Main Effects and Interaction Effects with Group for Measures of Spontaneous Facial Expressions to Odors (Condition 1)

		Responsiveness		Accuracy		Intensity	
Effect	Level	Mean	(s.d).	Mean	(s.d)	Mean	(s.d)
Group (G)	LHDs	**.66**	(.17)	**.52**	(.12)	**1.85**	(.45)
	RHDs	**.55**	(.21)	**.55**	(.09)	**1.71**	(.38)
	NCs	**.60**	(.19)	**.56**	(.11)	**1.71**	(.30)
Valence (V)	Pleasant	**.56**	(.19)	**.32**	(.23)	**1.67**	(.34)
	Unpleasant	**.63**	(.22)	**.76**	(.20)	**1.85**	(.57)
G X V							
LHD	Pleasant	.61	(.17)	.29	(.22)	1.68	(.37)
	Unpleasant	.71	(.21)	.75	(.25)	2.02	(.67)
RHD	Pleasant	.52	(.22)	.37	(.26)	1.70	(.37)
	Unpleasant	.57	(.22)	.73	(.19)	1.73	(.48)
NC	Pleasant	.57	(.17)	.30	(.22)	1.62	(.27)
	Unpleasant	.62	(.23)	.82	(.15)	1.80	(.55)
Nostril (N)	Right	.58	(.20)	.55	(.15)	1.73	(.39)
	Left	.61	(.21)	.54	(.15)	1.79	(.48)
G X N							
LHD	Right	.63	(.18)	.54	(.12)	1.76	(.44)
	Left	.68	(.19)	.49	(.14)	1.94	(.54)
RHD	Right	.55	(.22)	.57	(.15)	1.70	(.44)
	Left	.55	(.22)	.53	(.15)	1.72	(.45)
NC	Right	.58	(.21)	.52	(.18)	1.73	(.29)
	Left	.61	(.20)	.60	(.14)	1.69	(.44)

Note: Findings discussed in text are highlighted in Table.

Two trends did emerge within each spontaneous expression condition regarding interaction effects with Group. First, for Condition 1, a trend for the measure of accuracy occurred for the interaction between Group, Valence and Nostril (see Table 11), but findings were not consistent with the a priori hypotheses. Post-hoc analyses on all possible comparisons indicated that the only significant Group differences to emerge were for unpleasant odorants presented to the left nostril. Here, RHDs responses were rated as being less accurate than NCs, with no differences observed for the LHD group.

The second trend to emerge was between Group and Valence for the measure of responsivity in the condition where highly unpleasant odorants were used (Condition 5)

(see Table 10). There were no differences between the groups as a function of Valence, and thus results did not support the Valence hypothesis. However, both LHDs and RHDs were rated as making more hedonic responses to unpleasant odors than to pleasant odors, whereas this effect was not observed for the NCs.

Table 9. Results of ANOVAs for Spontaneous Expressions to Highly Unpleasant Odors (Condition 5) for Measures of Responsivity, Accuracy, and Intensity

	Responsivity			Accuracy			Intensity		
Source	df	F	p	df	F	p	df	F	p
Between Subjects									
Group (G)	2	.33	.72	2	1.37	.27	2	1.09	.35
S within-group error	38	(.18)		36	(.09)		36	(.87)	
Within Subjects									
Valence (V)	1	21.95	.000	1	69.47	.000	1	11.65	.002
G X V	2	2.88	.07	2	.19	.83	2	.61	.55
V x S within-group error	38	(.05)		36	(.16)		36	(.45)	
Within Subjects									
Nostril (N)	1	1.66	.21	1	.09	.77	1	.08	.78
G x N	2	.12	.89	2	.66	.52	2	.28	.76
N x S within-group error	38	(.05)		36	(.03)		36	(.34)	
Within Subjects									
V x N	1	.28	.59	1	.03	.87	1	.76	.39
G x V x N	2	.03	.97	2	.08	.92	2	.07	.93
V x N x S within-group error	38	(.04)		36	(.04)		36	(.21)	

Note: Values enclosed in parentheses represent mean square errors

Table 10. Means of Main Effects and Interaction Effects with Group for Measures of Spontaneous Facial Expressions to Highly Unpleasant Odors (Condition 5)

		Responsiveness		**Accuracy**		**Intensity**	
Effect	Level	Mean	(s.d.)	Mean	(s.d)	Mean	(s.d)
Group (G)	LHDs	**.61**	(.16)	**.57**	(.19)	**1.71**	(.52)
	RHDs	**.54**	(.24)	**.49**	(.13)	**1.90**	(.53)
	NCs	**.57**	(.24)	**.56**	(.10)	**1.82**	(.45)
Valence (V)	Pleasant	**.49**	(.24)	**.27**	(.27)	**1.61**	(.48)
	Unpleasant	**.65**	(.24)	**.81**	(.22)	**1.99**	(.71)
G X V							
LHD	Pleasant	**.49**	(.22)	.30	(.32)	1.45	(.43)
	Unpleasant	**.73**	(.15)	.84	(.27)	1.97	(.74)
RHD	Pleasant	**.45**	(.26)	.21	(.22)	1.69	(.65)
	Unpleasant	**.63**	(.24)	.75	(.22)	2.09	(.80)
NC	Pleasant	**.54**	(.24)	.28	(.27)	1.72	(.33)
	Unpleasant	**.59**	(.31)	.84	(.15)	1.91	(.63)
Nostril (N)	Right	.55	(.23)	.55	(.20)	1.81	(.56)
	Left	.59	(.24)	.54	(.16)	1.80	(.58)
G X N							
LHD	Right	.60	(.17)	.59	(.21)	1.72	(.65)
	Left	.62	(.20)	.56	(.20)	1.70	(.50)
RHD	Right	.51	(.27)	.50	(.25)	1.96	(.46)
	Left	.57	(.26)	.50	(.11)	1.85	(.74)
NC	Right	.54	(.27)	.56	(.15)	1.77	(.54)
	Left	.59	(.27)	.56	(.14)	1.87	(.55)

Note: Findings discussed in text are highlighted in Table.

Table 11. Means and Standard Deviations (in parentheses) for Spontaneous Expressions to Odors (Condition 1) for Accuracy as a Function of Group, Valence and Nostril

		Group		
Nostril	Valence	LHD	RHD	NC
Right	Pleasant	.34 (.29)	.35 (.29)	.29 (.27)
	Unpleasant	.74 (.28)	.78 (.20)	.77 (.23)
Left	Pleasant	.23 (.23)	.39 (.29)	.31 (.29)
	Unpleasant	**.75** (.26)	**.67** (.28)	**.88** (.21)

Note: Findings discussed in text are highlighted in Table.

Since certain factors, such as general olfactory ability, cognitive abilities, extent of facial paralysis and presence of buccofacial apraxia, may influence findings from the

experimental condition, the role of such factors on the experimental measures were examined (see Appendix 5). However, none of these factors correlated significantly with the experimental measures.

Although group performances were not significantly influenced by valence of the odor, a significant main effect of Valence was observed for all ratings of spontaneous expressions to odors. Thus, the expressions produced were judged to be more hedonically responsive, more accurate, and more intense when unpleasant odors were presented in comparison to pleasant odors. This effect can be seen by examining the mean values for pleasant and unpleasant odors, as shown in Tables 8 and 10.

Prompted Expressions to Odors. When subjects were instructed to produce expressions to indicate how the odor made them feel, there were no significant main effect for Group for any measure, as shown in Tables 12 and 13. However, there were significant interaction effects with Group for each of the 3 facial expression measures.

A significant Group by Nostril interaction was observed for the responsivity measure, but findings were not consistent with the Right Hemisphere hypothesis. As shown in Table 13, LHDs were judged as making significantly fewer hedonic responses than NCs when odors were presented to the right nostril, with no significant differences emerging for the RHDs. No significant group differences emerged when odors were presented to the left nostril.

Table 12. Results of ANOVAs for Prompted Expressions to Odors (Condition 2) for Measures of Responsivity, Accuracy and Intensity

	Responsivity			Accuracy			Intensity		
Source	df	F	p	df	F	p	df	F	p
Between Subjects									
Group (G)	2	1.45	.24	2	.97	.39	2	.87	.42
S within-group error	55	(.14)		55	(.13)		55	(3.27)	
Within Subjects									
Valence (V)	1	14.16	.000	1	3.50	.07	1	11.59	.001
G x V	2	1.81	.17	2	.87	.42	2	3.16	.05
V x S within-group error	55	(.05)		55	(.21)		55	(1.68)	
Within Subjects									
Nostril (N)	1	.78	.38	1	.90	.35	1	9.58	.003
G x N	2	3.59	.03	2	1.07	.35	2	.93	.40
N x S within-group error	55	(.02)		55	(.04)		55	(.62)	
Within Subjects									
V x N	1	2.15	.15	1	2.69	.11	1	1.81	.18
G x V x N	2	2.48	.09	2	3.69	.03	2	.44	.65
V x N x S within-group error	55	(.02)		55	(.02)		55	(.45)	

Note: Values enclosed in parentheses represent mean square errors.

Table 13. Means of Main Effects and Interaction Effects with Group for Measures of Prompted Facial Expressions to Odors (Condition 2)

		Responsiveness		Accuracy		Intensity	
Effect	Level	Mean	(s.d.)	Mean	(s.d)	Mean	(s.d)
Group (G)	LHDs	**.68**	(.19)	**.72**	(.15)	**3.52**	(.80)
	RHDs	**.75**	(.22)	**.71**	(.23)	**3.72**	(1.05)
	NCs	**.78**	(.14)	**.78**	(.14)	**3.92**	(.85)
Valence (V)	Pleasant	**.69**	(.23)	**.68**	(.33)	**3.43**	(1.07)
	Unpleasant	**.79**	(.21)	**.79**	(.23)	**4.01**	(1.19)
G X V							
LHD	Pleasant	.66	(.22)	.64	(.32)	**3.53**	(1.08)
	Unpleasant	.70	(.21)	.79	(.20)	**3.52**	(.99)
RHD	Pleasant	.70	(.27)	.64	(.42)	**3.23**	(1.15)
	Unpleasant	.80	(.22)	.79	(.27)	**4.21**	(1.42)
NC	Pleasant	.70	(.18)	.78	(.21)	**3.53**	(1.00)
	Unpleasant	.87	(.16)	.78	(.24)	**4.30**	(.96)
Nostril (N)	Right	.74	(.19)	.75	(.21)	3.55	(.93)
	Left	.73	(.22)	.72	(.21)	3.89	(1.04)
G X N							
LHD	Right	**.68**	(.19)	.73	(.17)	3.27	(.72)
	Left	.68	(.22)	.70	(.20)	3.78	(1.04)
RHD	Right	**.73**	(.19)	.69	(.26)	3.55	(.94)
	Left	.77	(.24)	.72	(.24)	3.83	(1.19)
NC	Right	**.83**	(.15)	.81	(.16)	3.83	(1.03)
	Left	.74	(.18)	.75	(.18)	4.00	(.89)

Note: Findings discussed in text are highlighted in Table.

When accuracy of the prompted expressions was examined, a significant interaction emerged between Group, Valence and Nostril. When post-hoc comparisons were done, results indicated that RHDs were less accurate in making expressions to pleasant odors than NCs when odors were presented to the right nostril, with no differences emerging for the LHD group (see Table 14). When odorants were presented to the left nostril, no significant group effects emerged for the post-hoc comparisons. These findings provide partial support for the Right Hemisphere hypothesis.

Table 14. Means and Standard Deviations for Prompted Expressions to Odors (Condition 2) for Accuracy as a Function of Group, Valence and Nostril

		Group		
Nostril	Valence	LHD	RHD	NC
Right	Pleasant	**.67** (.34)	**.58** (.43)	**.86** (.20)
	Unpleasant	.80 (.24)	.80 (.32)	.76 (.28)
Left	Pleasant	.62 (.35)	.63 (.44)	.69 (.33)
	Unpleasant	.79 (.26)	.80 (.27)	.80 (.24)

Note: Findings discussed in text are highlighted in Table.

Findings for intensity of prompted facial expressions revealed a significant interaction between Group and Valence (see mean values in Table 13), but findings did not support either hypothesis. Post-hoc comparisons indicated that no group comparisons were significant. However, expressions to unpleasant odors produced by RHDs and NCs were rated as being more intense than those made to pleasant odors. This effect was not seen for the LHD subjects.

Lastly, a trend emerged between Group, Valence, and Nostril for the responsivity measure, but the results did not support the a priori hypotheses. Post-hoc comparisons indicated there were no significant group differences, but did reveal that for LHDs, side of nostril presentation had no effect on ratings of responsivity for either pleasant or unpleasant odors. Both RHDs and NCs were rated as being less responsive to pleasant than to unpleasant odors when odors were administered to the left nostril; this effect was not predicted. In addition, the responses of the NCs were judged to be more responsive when pleasant odors presented to the right nostril, in comparison to the left nostril.

The interaction effects with Nostril reported above suggests that the group differences are not due to LHDs' or RHDs' poorer ability in identifying odors, assessed by

performance on the Smell Identification Test, which was used as a covariate in a subsequent ANCOVA. Likewise, ability to produce prompted facial expressions to odors was not influenced by extent of facial paralysis or presence of buccofacial apraxia for any group (see Appendix 5).

Several other findings seen for measures assessing prompted facial expression to odors included a main effect for Valence. As was the case for spontaneous expressions to odors, subjects' expressions were rated as being significantly more hedonically responsive and more intense for unpleasant in comparison to pleasant odors. There was also a tendency for expressions to be rated more accurately when unpleasant odors were administered in comparison to pleasant odors. Mean values for this effect are shown in Table 13.

Lastly, a main effect for Nostril emerged regarding the intensity of the prompted expressions produced. Raters judged expressions to be more intense when odors were presented to the left nostril in comparison to the right nostril (see Table 13 for mean values).

Subjective Ratings of Odors. Facial expressions are examples of an indicator of experiential states. Also of interest in the current study was whether there were any group differences in subjective ratings of the odors. Results from the ANOVAs completed for each measure from the self-report ratings are shown in Table 15, with means and standard deviations presented in Table 16.

Consistent with the findings reported for spontaneous and prompted facial expressions to odors, no significant main effects emerged for Group. Thus, the subjective

ratings of hedonic responsivity, accuracy, and intensity made by LHDs, RHDs, and NCs did not significantly differ. However, a significant interaction between Group and Nostril did emerge for ratings of hedonic intensity. Post hoc comparisons indicated that when odorants were presented to the right nostril, the RHDs rated the odors as being significantly less intense than LHDs, with no differences emerging for the NCs (see Table 16). However, no Group differences emerged when odorants were presented to the left nostril.

Table 15. Results of ANOVAs for Subjective Ratings of Odors (Condition 3) for Measures of Responsivity, Accuracy and Intensity

	Responsivity			Accuracy			Intensity		
Source	df	F	p	df	F	p	df	F	p
Between Subjects									
Group (G)	2	.15	.86	2	1.62	.21	2	2.23	.12
S within-group error	54	(.08)		53	(.09)		53	(8.17)	
Within Subjects									
Valence (V)	1	4.51	.04	1	2.26	.14	1	6.76	.01
G x V	2	1.71	.19	2	.60	.55	2	.13	.88
V x S within-group error	54	(.04)		53	(.10)		53	(3.81)	
Within Subjects									
Nostril (N)	1	2.77	.10	1	1.62	.21	1	.29	.60
G x N	2	.56	.57	2	.28	.76	2	4.56	.02
N x S within-group error	54	(.03)		53	(.03)		53	(1.51)	
Within Subjects									
V x N	1	1.32	.26	1	2.92	.09	1	1.59	.21
G x V x N	2	.06	.94	2	1.65	.20	2	.07	.94
V x N x S within-group error	54	(.03)		53	(.03)		53	(1.08)	

Note: Values enclosed in parentheses represent mean square errors.

Table 16. Means of Main Effects and Interaction Effects with Group for the Measures of Subjective Ratings of Odors (Condition 3)

		Responsivity		Accuracy		Intensity	
Effect	Level	Mean	(s.d.)	Mean	(s.d)	Mean	(s.d)
Group (G)	LHDs	**.84**	(.17)	**.91**	(.13)	**6.21**	(1.44)
	RHDs	**.87**	(.12)	**.84**	(.19)	**5.27**	(1.57)
	NCs	**.87**	(.13)	**.92**	(.11)	**5.36**	(1.42)
Valence (V)	Pleasant	**.83**	(.19)	**.89**	(.25)	**5.28**	(1.89)
	Unpleasant	**.89**	(.15)	**.92**	(.15)	**5.95**	(1.69)
G X V							
LHD	Pleasant	.85	(.23)	.89	(.25)	5.91	(1.77)
	Unpleasant	.84	(.19)	.93	(.12)	6.52	(2.00)
RHD	Pleasant	.83	(.13)	.77	(.33)	5.00	(2.00)
	Unpleasant	.90	(.14)	.90	(.19)	5.55	(1.38)
NC	Pleasant	.81	(.22)	.91	(.18)	4.94	(1.83)
	Unpleasant	.93	(.10)	.93	(.13)	5.78	(1.60)
Nostril (N)	Right	.84	(.17)	.90	(.16)	5.63	(1.73)
	Left	.88	(.16)	.87	(.18)	5.59	(1.58)
G X N							
LHD	Right	.83	(.18)	.91	(.15)	**6.47**	(1.56)
	Left	.86	(.20)	.90	(.16)	6.00	(1.64)
RHD	Right	.86	(.17)	.85	(.20)	**5.00**	(1.78)
	Left	.88	(.14)	.83	(.22)	5.57	(1.61)
NC	Right	.83	(.18)	.94	(.09)	**5.48**	(1.55)
	Left	.91	(.12)	.90	(.16)	5.22	(1.50)

Note: Findings discussed in text are highlighted in Table.

Similar to the facial expression conditions, significant Valence effects emerged for measures of responsivity and intensity. Therefore, the subjects' ratings indicated that they were more hedonically responsive and found odorants more hedonically intense when unpleasant odors were presented in comparison to pleasant odors. The means and standard deviations for each of these measures are reported in Table 16 .

Interestingly, there was no significant main effect for Valence for accuracy, indicating that valence of the odor had no effect on the subjects' ability to categorize the odors as pleasant or unpleasant. A trend between Nostril and Valence emerged for the measure of accuracy. Post-hoc analyses indicated that there was a tendency for

participants to more accurately rate hedonic quality when pleasant odors were presented to the right nostril (M = .88) than to the left nostril (M = .82). In contrast, there were no differences in accuracy ratings for unpleasant odors between the right (M = .92) and left (M = .92) nostrils.

Lastly, a trend was seen for Nostril on the responsivity measure. Participants tended to rate odorants as having a hedonic quality (i.e., pleasant or unpleasant) when odorants were presented to the left (M = .88) than right (M = .84) nostril.

Subjective ratings of odorants were not influenced by general olfactory ability, as measured by the Smell Identification Test. Thus, when olfactory identification abilities were controlled for (ANCOVA), group differences on this control task had no bearing on the subjective rating measures.

Behavioral Choice Measure. A forced choice procedure was done to ascertain if choice behavior of the LHDs, RHDs, or NCs would differ when subjects were instructed to perform in a goal-directed fashion. A mixed design repeated measures ANOVA was completed to examine effects of Group and Nostril and results are presented in Table 17. There were no significant effects, however, a trend emerged for Group. Although post-hoc comparisons were not significant, LHDs (M = 2.55, sd = .60) chose fewer pleasant odors than RHDs (M = 2.78, sd = .46) or NCs (M = 2.89, sd = .21).

Table 17. Results of ANOVA for Behavioral Choice Measure (Condition 4)

Source	df	F	p
Between Subjects			
Group (G)	2	2.65	.08
S within-group error	55	(.42)	
Within Subjects			
Nostril (N)	1	.94	.34
G x N	2	2.32	.11
N x S within-group error	55	(.18)	

Note: Values enclosed in parentheses represent mean square errors.

Findings from Posed Hedonic and Emotional Facial Expressions Elicited Without Using Odorants

As stated earlier, it was of interest to determine how expressions to odorants would differ from hedonic and emotional facial expressions produced without using odorants. The parameters used for the posed hedonic expression condition and the posed facial expressions to six discrete emotions are shown in Table 18, which also describes the scale range for each parameter. Measures from the posed hedonic expression condition were examined by using separate mixed design, repeated measure ANOVAs, with Group as a between subjects factor and Valence (pleasant, unpleasant) as a within subjects factor. For the posed emotional expressions to 6 discrete emotions, one way ANOVAs were done on mean scores for each measure. Post hoc tests were done using Newman-Keuls multiple comparison procedures for all possible comparisons.

Table 18. Parameters for Posed Hedonic Expression and Posed Emotional Expression Conditions with Score Ranges and Parameter Description

Condition	Parameter	Score range	Parameter Description
Prompted Hedonic Expressions	Responsivity*	0-1	Whether or not the hedonic quality of the response was judged to be pleasant/unpleasant vs. neither
	Accuracy**	0-1	Whether or not the judgment of hedonic quality of the response agreed with the pose instructed
	Intensity***	1-10	Degree of musculature involvement on the face
Posed Facial Expressions to Six Discrete Emotions	Accuracy**	0-1	Whether or not the resulting expression, as judged by the raters, was the same as the pose instructed to the subject
	Confidence Ratings‡	1-5	Raters' degree of confidence in their judgment of the type of emotion expressed by the subject
	Intensity±	1-7	Degree of musculature involvement on the face

* From neither pleasant/unpleasant (low) to pleasant/unpleasant (high).
**From inaccurate (low) to accurate (high).
*** Absolute value for measure (score range: -10 to +10); from none/minimal (low) to maximal (high).
‡ From not at all confident (low) to extremely confident (high).
± From minimal (low) to maximal (high).

Posed Hedonic Expressions. Similar to findings reported for facial expressions to the odors, posed hedonic expressions without odors for the LHD, RHD and NC subjects did not differ in terms of ratings of hedonic responsivity, judgments of accuracy for instructed pose, or ratings of intensity of the expression. These findings were unrelated to the extent of facial paralysis or to measures of buccofacial apraxia, with no significant correlations emerging between these measures and the posed hedonic expression measures (see Appendix 5). Results from the ANOVAs are presented in Table 19; means and standard deviations for each effect are reported in Table 20.

Table 19. Results of ANOVAs for Posed Hedonic Expressions for Measures of Responsivity, Accuracy and Intensity

	Responsivity			Accuracy			Intensity		
Source	df	F	p	df	F	p	df	F	p
Between Subjects									
Group (G)	2	1.96	.15	2	.43	.65	2	1.75	.19
S within-group error	55	(.09)		49	(.07)		49	(3.18)	
Within Subjects									
Valence (V)	1	1.28	.26	1	.17	.69	1	1.37	.25
G x V	2	1.06	.35	2	.34	.71	2	1.13	.33
V x S within-group error	55	(.08)		49	(.07)		49	(.76)	

Note: Values enclosed in parentheses represent mean square errors.

Table 20. Means for Main Effects and Interactions with Group for Measures of Posed Hedonic Expressions

		Responsivity		Accuracy		Intensity	
Effect	Level	Mean	(s.d.)	Mean	(s.d)	Mean	(s.d)
Group (G)	LHDs	.88	(.16)	.86	(.21)	3.47	(1.16)
	RHDs	.75	(.25)	.86	(.25)	2.57	(1.32)
	NCs	.80	(.20)	.87	(.23)	3.10	(1.38)
Valence (V)	Pleasant	.84	(.28)	.88	(.26)	3.13	(1.40)
	Unpleasant	.78	(.30)	.86	(.30)	3.00	(1.45)
G x V							
LHD	Pleasant	.96	(.10)	.88	(.30)	3.62	(1.18)
	Unpleasant	.80	(.32)	.82	(.30)	3.32	(1.24)
RHD	Pleasant	.76	(.31)	.83	(.28)	2.47	(1.35)
	Unpleasant	.75	(.32)	.91	(.24)	2.80	(1.55)
NC	Pleasant	.81	(.32)	.93	(.17)	3.34	(1.47)
	Unpleasant	.80	(.29)	.84	(.35)	2.90	(1.60)

Posed Facial Expressions to Six Discrete Emotions. Besides having subjects pose pleasant and unpleasant expressions, participants were also instructed to pose facial expressions to six discrete emotions to verbal commands. Significant group differences emerged for every measure, as seen in the results from the ANOVAs reported in Table 21, with means and standard deviations reported in Table 22. Post hoc comparisons for

accuracy indicated that emotional facial expressions made by LHDs and RHDs were rated less accurately than those produced by NCs, with no difference in ratings of accuracy between LHD and RHD subjects. The degree of confidence in the raters' judgments of accuracy significantly differed between all three groups, with raters being less confident in their accuracy judgments for RHDs (M = 2.20) than for LHDs (M = 2.56). Raters were also less confident in making accuracy judgments for both BD groups in comparison to NCs (M = 2.94). For intensity, expressions for the RHDs were rated as being significantly less intense than the NCs. The expressions for the LHDs did not differ in intensity when compared to the other two groups.

Table 21. Results of ANOVAs for Posed Facial Expressions to Six Discrete Emotions for Measures of Accuracy, Confidence Ratings and Intensity

	Accuracy			Confidence Ratings			Intensity		
Source	df	F	p	df	F	p	df	F	p
Between Subjects									
Group (G)	2	6.78	.002	2	8.91	.000	2	3.17	.05
S within-group error	55	(.03)		55	(.29)		55	(.75)	

Note: Values enclosed in parentheses represent mean square errors.

Table 22. Unadjusted Means of Main effects for Measures of Facial Expressions to Six Discrete Emotions

		Accuracy		Confidence Ratings		Intensity	
Main Effect	Level	Mean	(s.d.)	Mean	(s.d)	Mean	(s.d)
Group	LHDs	**.50**	(.22)	**2.56**	(.58)	**3.05**	(.94)
	RHDs	**.47**	(.17)	**2.20**	(.52)	**2.79**	(.91)
	NCs	**.66**	(.11)	**2.94**	(.52)	**3.48**	(.71)

Note: Findings discussed in text are highlighted in Table.

When factors such as extent of paralysis and presence of buccofacial apraxia were examined to determine if these factors played a role on the three measures, the only significant correlations to emerge were for accuracy (Appendix 5). Here, accuracy for posed facial expressions to six discrete emotions was influenced by the measures of buccofacial apraxia, but not extent of facial paralysis. Thus, this analysis was redone, using the buccofacial apraxia measures as a covariate. As before, significant Group effects emerged for accuracy ($F[2,55] = 5.35$; $p = .008$). Post-hoc comparisons were done on the adjusted means indicated that expressions for the RHDs ($\underline{M} = .45$) were rated as being significantly less accurate or appropriate than the NCs ($\underline{M} = .62$), with no significant differences emerging between the LHDs ($\underline{M} = .56$) and either of the other groups.

Another analysis was done to further explore group differences for confidence ratings. The rationale for including confidence ratings was to determine whether or not poses from a particular group were inaccurate due to the production of incorrect, but prototypical expressions, versus poses which were inaccurate due to poor ability to pose emotional expressions per se. In the first case, one would expect judgments of accuracy to be low and confidence ratings to be high, and in the latter case, one would expect judgments of accuracy to be low and confidence ratings to also be low. In order to take accuracy into account, a second analysis was done comparing group differences in the raters' confidence ratings by covarying for accuracy. When this ANCOVA was done, a significant Group difference was again found ($F[2,51] = 3.15$; $p = .05$). Adjusted means for LHDs, RHDs, and NCs, were, respectively as follows: 2.64, 2.35, 2.70. Post-hoc tests on the adjusted means indicated that confidence ratings were still significantly lower

for the RHDs in comparison to either the LHDs or NCs, but when controlling for accuracy scores, confidence ratings for LHDs and NCs were equivalent. These findings thus suggest that emotional facial expressions made by RHDs were less prototypical of a particular emotion than those produced by LHDs and NCs.

To better understand if the findings from this task supported either of the two hypotheses, effects of Valence were examined, by using separate 3 (Group) x 2 (Valence) repeated measure ANOVAs for each measure. Only one positive emotion (i.e., happy) was included in the task itself, and therefore, it was used as the measure for positive valence. For values of negative valence, three of the five remaining emotions were used in calculating an overall mean value: fear, disgust and sadness. The other emotions, surprise and anger, were not included, as it was reasoned that surprise may be either positively or negatively toned, and anger may contaminate potential valence effects, as it can be associated with approach-related (i.e., potentially left-hemisphere based) emotions (Davidson, 1993).

There were no significant Group by Valence effects for measures of accuracy or intensity, as shown in Tables 23 and 24. The only significant interaction effect to emerge between Group and Valence was for confidence ratings. When post-hoc comparisons were done for each level of Valence, for positive emotion, raters were significantly less confident in ratings of RHDs' expressions than NCs and LHDs, with no difference between LHDs and NCs. For negative emotions, raters were significantly less confident in their ratings for both RHDs and LHDs in comparison to NCs, with no differences emerging between RHDs and LHDs.

When an ANCOVA was computed for confidence ratings controlling for ratings of accuracy (Group, $F(2,53) = 5.69$, $p = .006$), then post-hoc comparisons revealed that raters were less confident in rating the expressions of RHDs ($\underline{M} = 2.14$) than NCs ($\underline{M} = 2.60$), with no differences emerging for the LHDs ($\underline{M} = 2.37$). Post-hoc comparisons on adjusted means for the significant Group by Valence effect were also re-examined. For the positive emotion, raters were significantly less confident in their ratings for RHDs ($\underline{M} = 2.81$) than NCs ($\underline{M} = 3.45$) as well as LHDs ($\underline{M} = 3.76$), with no differences emerging between LHDs and NCs. For negative emotions, confidence ratings were significantly lower for RHDs ($M = 2.19$) in comparison to NCs ($M = 2.57$), with no difference emerging between RHDs and LHDs, or between LHDs and NCs.

In addition, the significant Group effect seen for accuracy, which previously included all six emotions, was now a trend ($p = .06$); adjusted means for overall accuracy for LHDs, RHDs, and NCs were, respectively, .66, .58 and .73. Thus, there was a tendency for expressions produced by RHDs to be rated less accurately than LHDs and NCs. For intensity, post-hoc comparisons revealed that RHDs expressions were rated as being less intense than NCs, with no differences emerging for the LHD group. Overall, in terms of effects of Group and Valence, the findings for facial expressions produced to six different emotions implicate a greater role of right hemisphere in emotional facial expression, regardless of emotional valence.

Table 23. Results of ANOVAs for Posed Facial Expressions to Six Discrete Emotions Examining Valence Effects for Measures of Accuracy, Confidence Ratings and Intensity

	Accuracy			Confidence Ratings			Intensity		
Source	df	F	p	df	F	p	df	F	p
Between Subjects									
Regression	2	1.28	.29	-			-		
Group (G)	2	3.04	.06	2	9.95	.000	2	4.15	.02
S within-group error	52	(.06)		54	(.87)		54	(1.90)	
Within Subjects									
Valence (V)	1	58.53	.000	1	73.12	.000	1	33.33	.000
G x V	2	1.40	.25	2	4.67	.01	2	1.50	.23
V x S within-group e error	54	(.07)		54	(.36)		54	(.51)	

Note: Values enclosed in parentheses represent mean square errors.

Table 24. Means of Main and Group by Valence Effects for the ANOVA Examining Valence Effects for Measures of Facial Expressions to Six Discrete Emotions

		Accuracy		Confidence Ratings		Intensity	
Main Effect	Level	Mean [Adj. mean]	(s.d.)	Mean	(s.d)	Mean	(s.d)
Group (G)	LHDs	.63 [.66]	(.21)	2.95	(.61)	3.32	(.96)
	RHDs	.58 [.58]	(.16)	2.31	(.72)	2.80	(1.00)
	NCs	.75 [.73]	(.14)	3.28	(.63)	3.66	(.94)
Valence (V)	Positive	.85	(.27)	3.32	(1.09)	3.61	(1.35)
	Negative	.47	(.25)	2.35	(.61)	2.86	(.90)
G x V							
LHD	Positive	.87	(.29)	**3.62**	(.87)	3.84	(1.10)
	Negative	.39	(.27)	**2.28**	(.58)	2.80	(.97)
RHD	Positive	.78	(.30)	**2.60**	(1.12)	3.00	(1.34)
	Negative	.40	(.23)	**2.07**	(.42)	2.57	(.87)
NC	Positive	.89	(.21)	**3.79**	(.87)	4.06	(1.43)
	Negative	.61	(.22)	**2.77**	(.63)	3.26	(.75)

Note: Values in brackets indicate means adjusted for covariate. Findings discussed in text are highlighted in Table.

A main effect of Valence was seen for all measures, where expressions were rated as being more accurate and more intense and where raters were more confident for positive than for negative emotions. Interestingly, this effect is opposite of the Valence effects seen when odorants were used to elicit expressions, where subjects were rated as being more expressive to unpleasant than to pleasant odors.

Given that group differences did emerge for the discrete emotion task, additional analyses were conducted to specifically explore whether group differences emerged as a function of each emotion (see Appendix 6). For accuracy, the Group by Emotion interaction was not significant, but significant interactions were seen for confidence ratings and for intensity. For fear and surprise, raters were less confident in expressions produced by both RHDs and LHDs in comparison to NCs, and the expressions produced by RHDs and LHDs were rated as being less intense than NCs. For happiness, raters were less confident in rating expressions produced by RHDs compared to LHDs and NCs, and RHDs' expressions were rated as being significantly less intense than both LHDs and NCs (no differences emerged between LHDs and NCs for these two measures). Confidence ratings for sadness and disgust indicated that raters were less confident in judgments made for both brain lesion groups in comparison to the NC group. For intensity, there were no significant group differences for sadness, whereas for disgust, only RHDs' expressions were rated as being less intense than NCs. For anger, raters were less confident rating expressions produced by RHDs, than both LHDs and NCs, with no differences emerging between LHDs and NCs; intensity ratings for anger did not differ between the three groups. Thus, although specific group effects were seen as a function of each emotion for

confidence ratings and intensity, this did not emerge for the measure of accuracy, and the overall findings tend to support the right hemisphere hypothesis.

Analyses Examining Intrahemispheric Effects on Experimental Measures

Subsequent analyses were conducted to compare and contrast inter- and intra-hemispheric effects on all experimental measures, including spontaneous and prompted facial expressions to odors, subjective ratings to odors and behavioral choice measures. For these analyses, a subset of participants from the HD groups were used, with subjects in each group having lesions either involving cortical posterior regions (LHDp= 8; RHDp = 8) or cortical anterior plus posterior regions (LHDa+p = 8; RHDa+p = 8).

As previously indicated, months post onset differed as a function of Lesion Site, with the posterior only subgroup being assessed more acutely (M = 7.5 months, sd = 10.8) than the anterior plus posterior subgroup (M = 27.7 months, sd = 29.3). Therefore, all analyses were done using months post onset as a covariate (see correlation analyses, shown in Appendix 5). The analyses for this section consisted of a mixed design, repeated measures 2 X 2 X 2 X 2 ANCOVAs, with Group (LHD, RHD) and Lesion Site (posterior only, anterior + posterior) as between-subject factors, and Valence (pleasant, unpleasant) and Nostril (right, left) as within-subject factors. Post-hoc comparisons by Newman-Keuls procedure were used to make subgroup comparisons (LHDp, LHDa+p, RHDp, RHDa+p), as well as within group comparisons. Analyses were not completed for Condition 5 (Spontaneous Expressions to Highly Unpleasant Odors), as fewer subjects participated in this condition than in other conditions (LHDp = 6; LHDa+p = 6; RHDp =

5; RHDp = 5), and it was felt that there was not sufficient power for analysis by ANCOVA.

For all analyses, results are considered significant when $p \leq .05$. Effects of interest are shown in Table 25, which are consistent with the a priori hypotheses. Since effects of Lesion Site were of particular interest in subsequent analyses, trends ($p \leq .10$) are only discussed when they involve interaction effects with Lesion Site.

If anterior regions are more involved in hedonic experience and expression, then significant effects are expected to emerge for Lesion Site (i.e., a main effect). However, if Lesion Site interacts with hemispheric side of lesion, than results can be predicted, based upon the right hemisphere and valence hypotheses. Table 25 shows the pattern of findings expected to emerge for such interactions, as well as the pattern of subgroup differences expected to emerge.

Table 25. Statistical Effects Expected to Emerge for Lesion Site for the Right Hemisphere and Valence Hypotheses

Source (if significant)	Right Hemisphere Hypothesis	Valence Hypothesis
Group (G) x Lesion Site (LS)	RHDa+p < RHDp < LHDp, LHDa+p	
G x Valence (V) Pleasant Unpleasant		 LHDa+p < LHDp, RHDp, RHDa+p RHDa+p < RHDp, LHDp, LHDa+p
G x LS x Nostril (N) Right Left	 RHDa+p < RHDp < LHDp, LHDa+p RHDa+p = RHDp = LHDp = LHDa+p	
G x LS x V x N Right pleasant Right unpleasant Left pleasant Left unpleasant		 RHDa+p < RHDp, LHDp, LHDa+p LHDa+p < LHDp, RHDp, RHDa+p

Spontaneous Facial Expressions to Odors. Spontaneous facial expressions did not differ in terms of ratings of hedonic responsivity, accuracy and intensity as a function of Lesion Site, as shown in Table 26. Mean values for the spontaneous facial expression measures are shown in Table 27.

Table 26. Results of ANOVAs Examining Intra-hemispheric Effects for Spontaneous Expressions to Odors (Condition 1) for Measures of Responsivity, Accuracy and Intensity

	Responsivity			Accuracy			Intensity		
Source	df	F	p	df	F	p	df	F	p
Between Subjects									
Regression	1	2.49	.13	1	.06	.81	1	3.39	.08
Group (G)	1	3.66	.07	1	.72	.40	1	.58	.46
Lesion Site (LS)	1	.81	.38	1	.26	.62	1	2.16	.15
G x LS	1	2.76	.11	1	.04	.85	1	2.36	.14
S within-group error	27	(.13)		27	(.06)		27	(.63)	
Within Subjects									
Valence (V)	1	11.64	.002	1	31.06	.000	1	6.28	.02
G x V	1	.30	.59	1	.09	.77	1	2.07	.16
LS x V	1	.02	.89	1	.13	.72	1	.98	.33
G x LS x V	1	.07	.80	1	.49	.49	1	6.11	.02
V x S within-group error	28	(.02)		28	(.17)		28	(.18)	
Within Subjects									
Nostril (N)	1	1.05	.32	1	.57	.46	1	.80	.34
G x N	1	1.11	.30	1	.46	.50	1	.75	.39
LS x N	1	1.12	.30	11	1.25	.27	1	1.31	.26
G x LS x N	1	2.03	.17	1	.44	.51	1	1.11	.30
N x S within-group error	28	(.02)		28	(.04)		28	(.23)	
Within Subjects									
V x N	1	.02	.90	1	.09	.77	1	.93	.34
G x V x N	1	.57	.46	1	3.45	.07	1	.89	.35
LS x V x N	1	.58	.45	1	.01	.91	1	3.55	.07
G x LS x V x N	1	4.12	.05	1	.01	.92	1	3.90	.06
V x N x S within-group error	28	(.02)		28	(.04)		28	(.13)	

Note: Values enclosed in parentheses represent mean square errors.

Table 27. Means of Main and Group by Lesion Site Effects for the ANOVA Examining Measures of Spontaneous Expressions to Odors (Condition 1)

		Responsivity		Accuracy		Intensity	
Effect	Level	Mean	(s.d.)	Mean	(s.d)	Mean	(s.d)
Group (G)	LHDs	.68	(.18)	.51	(.13)	1.87	(.47)
	RHDs	.56	(.21)	.55	(.10)	1.77	(.37)
Lesion site (LS)	p only	**.63**	(.21)	**.52**	(.15)	**1.87**	(.44)
	a + p	**.61**	(.20)	**.55**	(.07)	**1.76**	(.40)
G X LS							
LHD	p only	.75	(.13)	.50	(.17)	2.04	(.52)
	a + p	.62	(.19)	.53	(.07)	1.70	(.37)
RHD	p only	.51	(.21)	.54	(.13)	1.70	(.29)
	a + p	.61	(.21)	.56	(.06)	1.83	(.44)
Valence (V)	Pleasant	.57	(.20)	.33	(.24)	1.72	(.33)
	Unpleasant	.67	(.23)	.73	(.22)	1.91	(.59)
Nostril	Right	.61	(.21)	.54	(.14)	1.78	(.45)
	Left	.63	(.22)	.52	(.16)	1.86	(.51)

Note: Findings discussed in text are highlighted in Table.

As stated earlier, of interest in these analyses were interaction effects with Lesion Site. A significant four-way interaction emerged between Group, Lesion Site, Valence and Nostril for the measure of hedonic responsivity, yet the findings did not support either the Right Hemisphere or Valence Hypotheses. As shown in Table 28, participants with lesions in left posterior regions were rated as being significantly more responsive than subjects with right posterior lesions when pleasant odors were presented to the left nostril. Although this appeared to be the case for unpleasant odors presented to the left or right nostril, there were no other significant effects as a function of Lesion Site.

Table 28. Means and Standard Deviations for Spontaneous Expressions to Odors (Condition 1) for Responsivity as a Function of Group, Lesion Site, Valence and Nostril

		Group			
Nostril	Valence	LHDp	LHDa+p	RHDp	RHDa+p
Right	Pleasant	.61 (.11)	.58 (.26)	.53 (.26)	.53 (.31)
	Unpleasant	.78 (.23)	.67 (.21)	.50 (.23)	.68 (.24)
Left	**Pleasant**	**.79 (.11)***	**.55** (.19)	**.42** (.22)*	**.60** (.22)
	Unpleasant	.83 (.21)	.68 (.26)	.58 (.30)	.63 (.23)

* indicates significant differences by post-hoc comparisons.
Note: Findings discussed in text are highlighted in Table.

A significant interaction effect also emerged between Group, Lesion Site and Valence for ratings of intensity, shown in Table 29. Post-hoc comparisons revealed no significant differences between the lesion site groups as a function of odor valence and nostril. However, for the posterior LHD group, unlike the other lesion site groups, expressions were rated as being more intense to unpleasant odors in comparison to pleasant odors. No other within group comparisons were significant.

Table 29. Means and Standard Deviations for Spontaneous Expressions to Odors (Condition 1) for Intensity as a Function of Group, Lesion Site and Valence

	Group			
Valence	LHDp	LHDa+p	RHDp	RHDa+p
Pleasant	**1.77** (.34) *	1.68 (.42)	1.71 (.25)	1.73 (.36)
Unpleasant	**2.32** (.76) *	1.71 (.42)	1.68 (.43)	1.92 (.55)

* indicates significant differences by post-hoc comparisons.
Note: Findings discussed in text are highlighted in Table.

As before, a significant Valence effect emerged for judgments of hedonic responsivity, accuracy and hedonic intensity, with judges giving higher ratings for expressions made to unpleasant odors in comparison to pleasant odors.

Two trends with Lesion Site also emerged for the intensity measure. One was for the interaction between Group, Lesion Site, Valence and Nostril ($p = .06$) (see Table 30). When comparisons were made between the Lesion Site subgroups, there was only a tendency for expressions made to unpleasant odors presented to the right nostril to be rated more intensely for the posterior LHD group in comparison to the RHD posterior group. A trend was also seen for the interaction between Lesion Site, Valence and Nostril ($p = .07$), yet this effect is subsumed by the interaction previously described between Group, Lesion Site, Valence and Nostril.

Table 30. Means and Standard Deviations for Spontaneous Expressions to Odors (Condition 1) for Intensity as a Function of Group, Lesion Site, Valence and Nostril

		Group			
Nostril	Valence	LHDp	LHDa+p	RHDp	RHDa+p
Right	Pleasant	1.62 (.45)	1.55 (.28)	1.75 (.43)	1.70 (.41)
	Unpleasant	**2.31** (.90)*	**1.70** (.41)	**1.46** (.51)*	**2.15** (.66)
Left	Pleasant	1.91 (.43)	1.81 (.66)	1.68 (.30)	1.77 (.57)
	Unpleasant	2.02 (.74)	1.72 (.61)	1.90 (.42)	1.71 (.65)

* indicates trend via post-hoc comparisons.
Note: Findings discussed in text are highlighted in Table.

Prompted Expressions to Odors. Results of the ANCOVAs for all measures are shown in Table 31. Means and standard deviations for the 3 expressions measures for these analyses are displayed in Table 32.

Table 31. Results of ANOVAs Examining Intra-hemispheric Effects for Prompted Expressions to Odors (Condition 2) for Measures of Responsivity, Accuracy and Intensity

	Responsivity			Accuracy			Intensity		
Source	df	F	p	df	F	p	df	F	p
Between Subjects									
Regression	1	.62	.44	1	.02	.90	1	.80	.38
Group (G)	1	.21	.65	1	.02	.90	1	.46	.50
Lesion Site (LS)	1	.03	.86	1	.18	.67	1	.00	.97
G x LS	1	3.83	.06	1	.07	.79	1	1.60	.22
S within-group error	27	(.16)		27	(.19)		27	(3.20)	
Within Subjects									
Valence (V)	1	3.67	.07	1	5.41	.03	1	4.56	.04
G x V	1	.66	.42	1	.36	.55	1	7.29	.01
LS x V	1	.00	.96	1	.01	.92	1	.01	.94
G x LS x V	1	1.42	.24	1	.41	.53	1	.62	.44
V x S within-group error	28	(.06)		28	(.26)		28	(1.92)	
Within Subjects									
Nostril (N)	1	.96	.34	1	.16	.69	1	11.12	.002
G x N	1	.03	.87	1	.03	.88	1	1.07	.31
LS x N	1	.27	.61	1	1.61	.22	1	.01	.91
G x LS x N	1	.68	.41	1	.15	.70	1	1.61	.21
N x S within-group error	28	(.02)		28	(.04)		28	(.33)	
Within Subjects									
V x N	1	.03	.86	1	1.13	.30	1	.30	.59
G x V x N	1	.01	.91	1	3.54	.07	1	.27	.61
LS x V x N	1	3.86	.06	1	.02	.89	1	.37	.55
G x LS x V x N	1	3.13	.09	1	.05	.82	1	4.52	.04
V x N x S within-group error	28	(.01)		28	(.01)		28	(.48)	

Note: Values enclosed in parentheses represent mean square errors.

Table 32. Means of Main and Group by Lesion Site Effects for Measures of Prompted Expressions to Odors (Condition 2)

		Responsivity		Accuracy		Intensity	
Effect	Level	Mean	(s.d.)	Mean	(s.d)	Mean	(s.d)
Group (G)	LHDs	.71	(.17)	.71	(.15)	3.50	(.78)
	RHDs	.73	(.24)	.72	(.25)	3.71	(.98)
Lesion site (LS)	p only	.73	(.19)	.73	(.22)	3.67	(1.00)
	a + p	.72	(.22)	.70	(.19)	5.55	(.76)
G X LS							
LHD	p only	**.78**	(.14)	**.73**	(.13)	**3.74**	(.87)
	a + p	**.63**	(.17)	**.68**	(.18)	**3.25**	(.62)
RHD	p only	**.68**	(.23)	**.72**	(.30)	**3.58**	(1.18)
	a + p	**.80**	(.24)	**.71**	(.22)	**3.84**	(.79)
Valence (V)	Pleasant	.68	(.26)	.61	(.38)	3.34	(.99)
	Unpleasant	.76	(.22)	.82	(.24)	3.87	(1.29)
Nostril	Right	.71	(.20)	.72	(.23)	**3.44**	(.82)
	Left	.73	(.23)	.70	(.23)	**3.78**	(1.01)

Note: Findings discussed in text are highlighted in Table

For intensity, a significant four way interaction emerged for Group, Lesion Site, Valence and Nostril (see Table 33). There were no significant effects for Lesion Site subgroups as a function of Valence and Nostril. Within-group comparisons were not consistent with either the Right Hemisphere or Valence Hypotheses. These comparisons revealed that for left nostril presentations, expressions were significantly more intense to unpleasant odors than pleasant odors for the right posterior subgroup. This effect was also seen for the RHDa+p subgroup, with no such valence differences emerging for the LHD subgroups. For right nostril presentation, expressions were significantly more intense to unpleasant than to pleasant odors for the RHDa+p subgroup. No other valence differences emerged.

Table 33. Means and Standard Deviations for Prompted Expressions to Odors (Condition 2) for Intensity as a Function of Group, Lesion Site, Valence and Nostril

		Group			
Nostril	Valence	LHDp	LHDa+p	RHDp	RHDa+p
Right	Pleasant	3.36 (1.17)	3.34 (.96)	3.28 (1.11)	**2.85** (1.12)+
	Unpleasant	3.57 (1.13)	2.84 (.39)	3.79 (1.84)	**4.45** (.97)+
Left	Pleasant	4.10 (.71)	3.48 (1.43)	**2.91** (1.04)*	**3.43** (1.07)**
	Unpleasant	3.95 (1.17)	3.56 (1.07)	**4.35** (2.04)*	**4.62** (1.29)**

+, *, ** indicates significant differences between values by post-hoc comparisons.
Note: Findings discussed in text are highlighted in Table.

A significant Group by Valence interaction was seen for intensity of prompted expressions. Here, post hoc comparisons revealed that expressions produced by the LHDs (M = 3.43) were rated as being significantly less intense than RHDs (M = 4.30) when unpleasant odors were administered; no group differences emerged for pleasant odors (LHD M = 3.57; RHD M = 3.12).

Significant main effects for Valence were seen for accuracy and intensity, where raters judged expressions more accurately and as being more intense to unpleasant than to pleasant odors. A trend (p = .07) in the same direction emerged for responsivity, where facial responses made to unpleasant odors were rated as being more hedonically responsive than those made to pleasant odors. As before, a significant main effect for Nostril emerged for intensity, where expressions were rated as being more intense when odors were presented to the left in comparison to the right nostril (see Table 32).

Several trends emerged for responsivity ratings of the prompted expression condition with Group and Lesion Site as factors. This included an interaction between Group, Lesion Site, Valence and Nostril (p = .09) (see Table 34). No post-hoc comparisons for group were significant, but a trend was seen for unpleasant odors

presented to the left nostril. Here, expressions produced by subjects with left anterior plus posterior lesions were rated as being less hedonically responsive than those with right anterior plus posterior lesions when unpleasant odors were administered to the left nostril. No within-group comparisons were significant. A trend also emerged for Lesion Site, Valence and Nostril and between Group and Lesion Site. These two interaction effects are qualified by the four way interaction previously described. However, in terms of the interaction between Group and Lesion Site, the greatest differences in ratings of hedonic responsivity were for the anterior plus posterior groups, with expressions produced by the RHDa+p being rated as more hedonically responsive than the LHDa+p group.

Table 34. Means and Standard Deviations for Prompted Expressions to Odors (Condition 2) for Responsivity as a Function of Group, Lesion Site, Valence and Nostril

		Group			
Nostril	Valence	LHDp	LHDa+p	RHDp	RHDa+p
Right	Pleasant	.78 (.21)	.57 (.23)	.63 (.24)	.70 (.36)
	Unpleasant	.80 (.16)	.65 (.20)	.69 (.29)	.88 (.17)
Left	Pleasant	.68 (.27)	.70 (.25)	.66 (.30)	.73 (.37)
	Unpleasant	**.86** (.12)	**.62** (.28)	**.73** (.29)	**.89** (.16)

Note: Findings discussed in text are highlighted in Table.

Subjective Ratings of Odors. As for the facial expression conditions, there were no significant effects for the interaction between Group and Lesion Site for measures of hedonic responsivity, accuracy or intensity on the subjective ratings. Results of the ANOVAs conducted for each measure are reported in Table 35, with means and standard deviations for some of the effects shown in Table 36.

Table 35. Results of ANOVAs Examining Intra-hemispheric Effects for Subjective Ratings to Odors (Condition 3) for Measures of Responsivity, Accuracy and Intensity

	Responsivity			Accuracy			Intensity		
Source	df	F	p	df	F	p	df	F	p
Between Subjects									
Regression	1	1.52	.23	1	.96	.34	1	7.19	.01
Group (G)	1	.00	.99	1	2.65	.12	1	4.36	.05
Lesion Site (LS)	1	.26	.61	1	1.82	.19	1	1.20	.28
G x LS	1	.01	.93	1	.09	.76	1	1.46	.24
S within-group error	26	(.09)		26	(.13)		26	(3.20)	
Within Subjects									
Valence (V)	1	2.30	.14	1	3.01	.09	1	5.47	.03
G x V	1	1.19	.29	1	1.26	.27	1	.33	.57
LS x V	1	.06	.81	1	.55	.47	1	.56	.46
G x LS x V	1	3.53	.07	1	.35	.56	1	.45	.51
V x S within-group error	27	(.02)		27	(.14)		27	(3.19)	
Within Subjects									
Nostril (N)	1	.33	.57	1	.06	.81	1	.24	.63
G x N	1	.07	.79	1	.85	.37	1	3.74	.06
LS x N	1	.79	.38	1	1.19	.29	1	.00	.95
G x LS x N	1	3.32	.08	1	.01	.94	1	.01	.94
N x S within-group error	27	(.03)		27	(.03)		27	(.33)	
Within Subjects									
V x N	1	.70	.41	1	.79	.38	1	2.78	.11
G x V x N	1	.04	.85	1	.44	.51	1	.01	.92
LS x V x N	1	2.47	.13	1	.74	.40	1	.00	.98
G x LS x V x N	1	.02	.88	1	4.09	.05	1	.01	.93
V x N x S within-group error	27	(.03)		27	(.02)		27	(1.44)	

Note: Values enclosed in parentheses represent mean square errors.

Table 36. Means of Main and Group by Lesion Site Effects for the ANOVA Examining Measures of Subjective Ratings to Odors (Condition 3)

		Responsivity		Accuracy		Intensity	
Effect	Level	Mean	(s.d.)	Mean	(s.d)	Mean	(s.d)
Group (G)	LHDs	.88	(.17)	.91	(.14)	**6.28**	(1.53)
	RHDs	.88	(.11)	.81	(.21)	**5.25**	(1.68)
Lesion site (LS)	p only	.88	(.12)	.89	(.19)	5.72	(1.48)
	a + p	.88	(.16)	.83	(.17)	5.84	(1.89)
G X LS							
LHD	p only	**.88**	(.17)	**.95**	(.09)	**6.01**	(1.48)
	a + p	**.89**	(.18)	**.86**	(.17)	**6.55**	(1.66)
RHD	p only	**.89**	(.06)	**.82**	(.25)	**5.43**	(1.54)
	a + p	**.87**	(.16)	**.79**	(.17)	**5.04**	(1.93)
Valence (V)	Pleasant	.86	(.17)	.80	(.33)	5.41	(2.03)
	Unpleasant	.90	(.15)	.91	(.17)	6.14	(1.70)
Nostril	Right	.87	(.17)	.86	(.19)	5.72	(1.97)
	Left	.89	(.17)	.85	(.21)	5.84	(1.66)

Note: Findings discussed in text are highlighted in Table.

For accuracy, a four way interaction emerged between Group, Lesion Site, Valence and Nostril. Post hoc comparisons between the groups revealed no differences between the four subgroup as a function of Valence and Nostril. When post-hoc comparisons were done within each group, subjects with right anterior plus posterior lesions were significantly less accurate in making hedonic ratings of pleasant than unpleasant odors when odors were presented to the right nostril (see Table 37). However, no such valence effect emerged for any other lesion group when odors were presented to the left nostril.

Another significant effect to emerge (shown in Table 36), was for ratings of intensity for Group, where RHDs rated odors as being less intense than LHDs. This finding is consistent with the Right Hemisphere hypothesis.

Table 37. Means and Standard Deviations for Subjective Ratings to Odors (Condition 3) for Accuracy as a Function of Group, Lesion Site, Valence and Nostril

		Group			
Nostril	Valence	LHDp	LHDa+p	RHDp	RHDa+p
Right	Pleasant	.92 (.24)	.88 (.35)	.81 (.37)	**.64** (.39)*
	Unpleasant	.94 (.18)	.85 (.21)	.83 (.31)	**1.00** (.00)*
Left	Pleasant	.95 (.12)	.79 (.35)	.73 (.40)	.64 (.39)
	Unpleasant	1.00 (.00)	.91 (.15)	.92 (.24)	.86 (.34)

* indicates significant differences between values by post-hoc comparisons.
Note: Findings discussed in text are highlighted in Table.

For **responsivity**, no significant effects were seen. Two trends did emerge, one between Group, Lesion Site and Valence ($p = .07$), and the other for Group, Lesion Site and Nostril ($p = .08$). For the interaction with Valence, no differences emerged between the lesion site groups for the post hoc comparisons. When within-group comparisons were examined for each lesion site group, only participants with right posterior lesions tended to be more responsive to unpleasant than to pleasant odors (see Table 38). For the interaction with Nostril, again, no differences were found between the four lesion site groups for the post hoc comparisons. When within-group comparisons were conducted, participants with right anterior plus posterior lesions tended to be less responsive when odorants were presented to the right in comparison to the left nostril (Table 39).

Table 38. Means and Standard Deviations for Subjective Ratings to Odors (Condition 3) for Responsivity as a Function of Group, Lesion Site, and Valence

	Group			
Valence	LHDp	LHDa+p	RHDp	RHDa+p
Pleasant	.89 (.18)	.85 (.24)	**.83** (.09)*	.86 (.15)
Unpleasant	.85 (.19)	.92 (.13)	**.94** (.09)*	.88 (.19)

* indicates significant differences between values by post-hoc comparisons.
Note: Findings discussed in text are highlighted in Table.

Table 39. Means and Standard Deviations for Subjective Ratings to Odors (Condition 3) for Accuracy as a Function of Group, Lesion Site and Nostril

	Group			
Nostril	LHDp	LHDa+p	RHDp	RHDa+p
Right	.85 (.17)	.90 (.15)	.92 (.09)	**.81** (.24)*
Left	.90 (.18)	.88 (.23)	.85 (.17)	**.93** (.13)*

* indicates significant differences between values by post-hoc comparisons.
Note: Findings discussed in text are highlighted in Table.

Behavioral Choice Measure. Results of this ANOVA are shown in Table 40. No significant Group by Lesion Site effect emerged, but two trends were seen. One was for the interaction between Group and Nostril ($p = .08$). No post-hoc comparisons were significant, but each group chose fewer pleasant odors when odorants were presented to the nostril ipsilateral to the lesion (LHDs: Right $M = 2.69$, Left $M = 2.44$; RHDs: Right $M = 2.63$; Left $M = 2.81$).

The other trend to emerge was between Group, Lesion Site, and Nostril ($p = .08$). For this latter interaction (see Table 41), for the four subgroups, there was a trend for participants with left anterior plus posterior lesions to choose fewer pleasant odors when odorants were presented to the left in comparison to the right nostril. This difference as a function of nostril presentation was most prominent for this lesion group.

Table 40. Results of ANOVA Examining Intra-hemispheric Effects for the Behavioral Choice Measure (Condition 4)

Source	df	F	p
Between Subjects			
Regression	1	.77	.39
Group (G)	1	.54	.47
Lesion Site (LS)	1	.61	.44
G x LS	1	.28	.60
S within-group error	27	(.70)	
Within Subjects			
Nostril (N)	1	.07	.80
G x N	1	3.27	.08
LS x N	1	1.67	.21
G x LS x N	1	3.27	.08
N x S within-group error	28	(.23)	

Note: Values enclosed in parentheses represent mean square errors.

Table 41. Means and Standard Deviations for the ANOVA Examining Behavioral Choice Measures

	Group			
Nostril	LHDp	LHDa+p	RHDp	RHDa+p
Right	2.50 (.76)	**2.75** (.71)	.2.50 (.76)	2.88 (.35)
Left	2.63 (.74)	**2.25** (1.04)	2.88 (.35)	2.75 (.46)

Note: Findings discussed in text are highlighted in Table.

Presence of Avoidance Responses

Raters were asked to evaluate the presence of avoidance responses to odors during the two spontaneous expression condition conditions (Conditions 1 and 5), to determine whether there was a right hemisphere dominance for withdrawal/avoidant action tendencies. As for the analyses for the facial expression conditions, two mixed design repeated measures ANOVAs were done to evaluate these responses for each condition.

Newman-Keuls multiple comparison procedures were used when making all post-hoc comparisons. Table 42 reviews the score range and description for the avoidance responses.

Table 42. Parameter Description and Score Range for Avoidance Responses to Odors

Condition	Parameter	Score range	Rating Description
Spontaneous Expressions to Odors (Conditions 1 and 5)	Presence of Avoidant Responses*	0-1	Head turning away from odor; startle response; exaggerated blinking

* From none (low) to maximal (high).

As shown in Tables 43 and 44, there was a significant effect for Group for both lower intensity (Condition 1) and higher intensity (Condition 5) odor conditions. For the lower intensity odors, post hoc comparisons revealed that LHDs produced more avoidant responses than both RHDs and NCs. For higher intensity odors, LHDs produced more avoidant responses in comparison to RHDs but not NCs. No group differences emerged between RHDs and NCs for either condition.

Table 43. Results of ANOVAs Examining Presence of Avoidance Responses for Conditions 1 and 5

	Condition 1			Condition 5		
Source	df	F	p	df	F	p
Between Subjects						
Group (G)	2	3.55	.04	2	3.33	.05
S within-group error	55	(.09)		38	(.05)	
Within Subjects						
Valence (V)	1	15.28	.000	1	19.11	.000
G x V	2	.67	.51	2	.85	.44
V x S within-group error	55	(.01)		38	(.02)	
Within Subjects						
Nostril (N)	1	.00	.99	1	3.68	.06
G x N	2	.78	.47	2	1.04	.36
N x S within-group error	55	(.01)		38	(.02)	
Within Subjects						
V x N	1	1.54	.22	1	.19	.66
G x V x N	2	2.58	.09	2	.17	.84
V x N x S within-group error	55	(.01)		38	(.01)	

Note: Values enclosed in parentheses represent mean square errors.

Table 44. Means of Main and Interaction Effects with Group for Presence of Avoidance Responses for Conditions 1 and 5

		Condition 1		Condition 5	
Effect	Level	Mean	(s.d.)	Mean	(s.d)
Group (G)	LHDs	**.16**	(.22)	**.16**	(.16)
	RHDs	**.06**	(.12)	**.07**	(.09)
	NCs	**.04**	(.05)	**.06**	(.08)
Valence (V)	Pleasant	.06	(.13)	.05	(.11)
	Unpleasant	.12	(.20)	.14	(.16)
G X V					
LHD	Pleasant	.12	(.19)	.10	(.16)
	Unpleasant	.20	(.27)	.21	(.17)
RHD	Pleasant	.03	(.10)	.04	(.06)
	Unpleasant	.09	(.16)	.09	(.14)
NC	Pleasant	.02	(.03)	.01	(.02)
	Unpleasant	.06	(.08)	.11	(.15)
Nostril (N)	Right	.09	(.17)	.08	(.11)
	Left	.09	(.15)	.11	(.16)
G X N					
LHD	Right	.16	(.21)	.15	(.14)
	Left	.16	(.25)	.17	(.21)
RHD	Right	.07	(.13)	.02	(.06)
	Left	.05	(.12)	.10	(.14)
NC	Right	.03	(.05)	.05	(.08)
	Left	.04	(.07)	.06	(.11)

Note: Findings discussed in text are highlighted in Table.

It is interesting to note that a greater number of avoidant responses were expected for the highly unpleasant odorants (Condition 5). However, examination of the mean values for Group in Table 44 suggests that there was an equivalent number of avoidant responses made within the two conditions. In addition the magnitude of responses for each group as a function of valence was also similar for both Conditions.

Similar to findings for the expression conditions, a significant effect for Valence emerged for each condition. As expected, a greater number of avoidant responses were produced to unpleasant odors than to pleasant odors.

Two trends were seen in the above analyses. One was for Nostril ($p = .06$) when highly unpleasant odors (Condition 5) were administered. As shown in Table 44, more avoidant responses were produced when odorants were administered to the left nostril in comparison to the right nostril. The other trend to emerge was an interaction between Group, Valence and Nostril ($p = .09$) for the lower intensity odors (Condition 1). As shown in Table 45, for pleasant odors, LHDs tended to make more avoidant responses to unpleasant odors in comparison to pleasants when odors were administered to the right versus left nostril. This effect was not seen in the other two groups.

Table 45. Means and Standard Deviations for Presence of Avoidance Responses for Condition 1 as a Function of Group, Valence and Nostril

		Group		
Nostril	Valence	LHD	RHD	NC
Right	Pleasant	**.09** (.18)	.04 (.11)	.02 (.04)
	Unpleasant	**.22** (.29)	.10 (.18)	.04 (.09)
Left	Pleasant	**.14** (.25)	.03 (.10)	.01 (.04)
	Unpleasant	**.19** (.27)	.07 (.15)	.07 (.11)

Note: Findings discussed in text are highlighted in Table.

In addition to examining group means and because of its clinical relevance, the performance of individual subjects was investigated. The data were examined to determine whether or not the majority (i.e., 5 out of 7) of the raters noted that an avoidance occurred for any given odorant trial for each subject. The number of subjects who had at least one trial rated by consensus of showing an avoidance response was noted for each group and for each condition. Because few of the RHDs and NCs elicited

avoidance responses, these groups were combined and compared to the LHD group in a 2 X 2 Chi square analysis.

For Condition 1, the Chi square analysis revealed a trend (Chi square corrected for continuity = 2.73, $p < .10$), with a greater number of LHDs demonstrating an avoidance response than the other groups combined. Here, 42% of the LHDs made at least one avoidance response by consensus, compared to 19% of RHDs and 17% of NCs. For Condition 5, the Chi square analysis was significant (Chi square = 4.46, $p = .03$), with a proportionately greater number of LHD subjects making avoidant responses than the other two groups combined. Here, 60% of the LHDs made avoidance responses, compared to 23% of the RHDs and 21% of the NCs.

Intrahemispheric Effects. To determine if a particular type of lesion (posterior only versus anterior plus posterior) was associated with an enhancement of avoidance responses in the LHD group, another mixed design, repeated measures ANOVA was done for responses elicited in Condition 1 using Lesion Site as a factor. As for the facial expression conditions, months post CVA onset was used as a covariate.

As shown in Tables 46 and 47, there were no significant Group by Lesion Site interactions. Of note is that for this subset of subjects, there were no longer significant effects of Group, although mean values were higher for the LHD group in comparison to the RHD group. However, a significant effect was seen for the interaction between Lesion Site and Nostril. When odorants were presented to the right nostril, ratings of avoidance responses were higher in the anterior plus posterior group than the posterior only group. The opposite effect occurred for odorants presented to the left nostril.

Table 46. Results of ANOVA Examining Intrahemispheric Effects for Presence of Avoidance Responses for Condition 1

	Condition 1		
Source	df	F	p
Between Subjects			
Regression	1	.44	.52
Group (G)	1	2.02	.17
Lesion Site	1	.22	.64
G x LS	1	.33	.57
S within-group error	27	(.16)	
Within Subjects			
Valence (V)	1	6.71	.02
G x V	1	.09	.77
LS x V	1	.01	.91
G x LS x V	1	.16	.69
V x S within-group error	28	(.02)	
Within Subjects			
Nostril (N)	1	.00	.95
G x N	1	1.36	.25
LS x N	1	4.05	.05
G x LS x N	1	1.35	.26
N x S within-group error	28	(.01)	
Within Subjects			
V x N	1	2.69	.11
G x V x N	1	.77	.39
LS x V x N	1	.20	.66
G x LS x V x N	1	.78	.38
V x N x S within-group error	28	(.01)	

Note: Values enclosed in parentheses represent mean square errors.

Table 47. Means of Main and Group by Lesion Site Effects for Avoidance Responses to Odors (Condition 1)

Effect	Level	Mean	(s.d.)
Group (G)	LHD	.17	(.24)
	RHD	.07	(.14)
Lesion site (LS)	p only	.11	(.20)
	a + p	.13	(.20)
G X LS			
LHD	p only	**.22**	(.32)
	a + p	**.11**	(.20)
RHD	p only	**.01**	(.02)
	a + p	**.06**	(.17)
Valence (V)	Pleasant	.09	(.17)
	Unpleasant	.15	(.24)
Nostril	Right	.12	(.19)
	Left	.12	(.22)
LS x N			
Right	p only	**.10**	(.17)
	a + p only	**.15**	(.21)
Left	p only	.13	(.24)
	a + p only	.11	(.21)

Note: Findings discussed in text are highlighted in Table.

Relationship Between Subjective Ratings and Facial Expressions to Odors

To examine the relationship between subjective ratings and facial expressions, intensity scores from subjective ratings (Condition 3) and from judges' ratings of intensity of facial expressions (Conditions 1 and 2) were correlated. A within-person correlational design would indicate the extent to which a person's subjective hedonic intensity rating was associated with the rated intensity of his or her facial expression. Similar to a procedure used by Kraut (1982), trials for pleasant and for unpleasant odors were considered separately. For each facial expression condition, correlations were computed for each subject between his or her evaluations of the odors and the judges' ratings of

facial expression on a trial-by-trial basis. Therefore, the correlation for each subject was based on 6 trials (e.g., 3 pleasant odors to the right nostril and 3 pleasant odors to the left nostril). Lower mean correlation values were expected if subjective experience and facial expression were dissociable. An r-to-z transformation was completed for correlations for each subject, and the transformed scores were entered into an ANOVA with group as an independent variable (statistical procedures are described in Michela, 1990).

Results of these analyses are shown in Tables 48 and 49. As shown, the highest correlations obtained between subjective ratings and facial expressions were for prompted expressions to unpleasant odors. Mean correlations for all other conditions were extremely low for all groups. In addition, no group differences emerged for either the spontaneous (Condition 1) or prompted (Condition 2) expression tasks for any analysis (Table 49).

Table 48. Average Correlations Between Experiential Ratings and Expression Conditions for LHDs, RHDs, and NCs

Condition	LHDs	RHDs	NCs
Spontaneous Expressions			
Pleasant Odors	-.11	.02	.01
Unpleasant Odors	.11	-.03	.17
Prompted Expressions			
Pleasant Odors	-.04	.12	.11
Unpleasant Odors	**.23**	**.26**	**.39**

Note: Findings discussed in text are highlighted in Table.

Table 49. Results of ANOVAs Examining Relationships Between Experiential Ratings (Condition 3) and Both Spontaneous Expressions (Condition 1) and Prompted Expressions (Condition 2) for Pleasant and Unpleasant Odors

Condition	F Ratio	df	p value
Spontaneous Expressions			
Pleasant Odors	.13	2,50	.88
Unpleasant Odors	.38	2,53	.68
Prompted Expressions			
Pleasant Odors	.20	2,48	.82
Unpleasant Odors	.19	2,53	.83

One difficulty with the above analyses is that the number of trials used in calculating correlations for each subject is small. In order to increase the number of cases included, a normalization procedure was done. Here, experiential and expression intensity scores were normalized separately for pleasant and unpleasant odors for each person, to control for intersubject (i.e., across-person) variance, as described by Michela (1990). Then, z-scores from the subjects' evaluations of the odors and the z-scores from the subjects' facial expression ratings were correlated on a case-by-case basis, and correlations were computed separately for each group. These correlation values are shown in Table 50.

Table 50. Average Correlations Between Normalized Experiential Ratings and Normalized Expression Ratings for LHDs, RHDs, and NCs

Condition	LHDs	RHDs	NCs
Spontaneous Expressions			
Pleasant Odors	-.07 (109)	-.02 (127)	.004 (78)
Unpleasant Odors	.11 (90)	.03 (103)	.20 (91)*
Prompted Expressions			
Pleasant Odors	-.12 (87)	.06 (97)	.18 (76)
Unpleasant Odors	.26 (92)**	.26 (104)**	.39 (98)***

Note: Values in parentheses indicate number of cases.
* $p = .06$
** $p \leq .01$
*** $p \leq .001$

As shown, the same pattern of findings is seen in Table 50 in comparison to Table 48. By increasing the "sample size", a trend was seen in the relationship between spontaneous expressions to subjective ratings to unpleasant odors for the control group ($p = .06$). Thus, in the healthy control group, there was a tendency where the more intense the experience produced by unpleasant odors, the greater the intensity of facial expressions produced spontaneously.

For the prompted expression condition, no significant relationships emerged for pleasant odors (Table 50). However, for unpleasant odors, significant correlations were found for all three groups. Therefore, when unpleasant odorants were experienced more intensely, all subjects were more likely to produce prompted facial expressions of greater intensity.

Relationship Among the Experimental Measures Within Each Condition

Examination of the relationships among the measures of hedonic facial expression and subjective rating conditions were of interest for several reasons. First, a significant relationship between measures would aid in the interpretation of the findings. For example, higher scores for responsivity may be the result of either presence of a facial expression or an avoidant response, and thus this type of analysis would help to indicate which measure (i.e., presence of avoidance response or intensity of the expression) played a greater role in responsivity scores. Secondly, coherence between measures may be expected for one group versus another. For example, if the right hemisphere plays a predominant role in emotional processing, than one might expect measures within each condition to be less correlated for the RHD group. On the other hand, if the valence hypothesis is operative, than one might expect that measures for pleasant odors to be less correlated in the LHD group in comparison to the RHD group, whereas measures for unpleasant odors would be less correlated in the RHD group in comparison to the LHD group.

For the two spontaneous expression conditions (Conditions 1 and 5), scores for responsivity, accuracy, intensity and presence of avoidance responses were intercorrelated. For the prompted expression condition (Condition 2) and for subjective ratings to odors (Condition 3), responsivity, accuracy and intensity were intercorrelated. Spearman rank order correlation coefficients were computed among the expression and experiential ratings separately for each group and for all subjects.

Intercorrelations for Condition 1. As seen in Table 51, the most consistent relationships to emerge between measures for each group were when unpleasant odors were presented. For unpleasant odors, responsivity and intensity were significantly correlated in all three groups. For the LHDs and RHDs, significant correlations between presence of avoidance responses and accuracy ratings were seen for unpleasant odorants presented to the right nostril. For RHDs, avoidance responses were positively correlated to responsivity for unpleasant odors presented to the left nostril. In addition, responsivity and intensity were significantly correlated for pleasant odors for the RHD group. For NCs, presence of avoidance responses and accuracy were negatively correlated for pleasant odors presented to the right nostril.

For all subjects together, responsivity and intensity significantly correlated regardless of nostril presentation or valence. In addition, presence of avoidance responses significantly correlated to the three other measures (responsiveness, accuracy and intensity) for unpleasant odors presented to the right nostril. A significant negative correlation was found between presence of avoidance responses to accuracy for pleasant odors presented to the right nostril.

Intercorrelations for Condition 5. Correlations between the measures for spontaneous expressions to highly unpleasant odors are seen in Table 52. No significant correlations emerged between measures for any group when pleasant odors were presented. For unpleasant odors presented to the left nostril, the following significant correlations emerged only for the RHD group: responsivity with intensity and presence of avoidance responses; accuracy with intensity; and intensity with presence of avoidance

Table 51. Intercorrelations Between Measures for Spontaneous Expressions to Odors (Condition 1) by Subject Group as a Function of Nostril Presentation and Valence

		Left Pleasant				Right Pleasant				Left Unpleasant				Right Unpleasant			
Subject Group	Measure	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
LHDs (n = 19)	1. Responsivity	--	-.18	.20	.50*	--	-.07	.33	.39	--	.24	.70**	.23	--	.09	.54*	.35
	2. Accuracy		--	.25	-.23		--	.19	-.43		--	.03	.30		--	-.03	.49*
	3. Intensity			--	-.29			--	.07			--	-.02			--	.42
	4. Avoidance				--				--				--				--
RHDs (n = 21)	1. Responsivity	--	.14	.55**	-.11	--	-.11	.55**	.22	--	.03	.72**	.43*	--	-.04	.65**	.30
	2. Accuracy		--	.01	-.06		--	-.36	.03		--	-.04	.08		--	-.06	.54**
	3. Intensity			--	-.37			--	-.07			--	.30			--	.24
	4. Avoidance				--				--				--				--
NCs (n = 18)	1. Responsivity	--	-.02	.38	.20	--	.17	.10	-.23	--	.14	.72**	.45	--	.35	.73*	.15
	2. Accuracy		--	.18	-.29		--	-.49*	-.57**		--	.34	.13		--	.22	.23
	3. Intensity			--	-.21			--	.34			--	.16			--	.33
	4. Avoidance				--				--				--				--
All Ss (n = 58)	1. Responsivity	--	-.04	.37**	.23	--	.00	.37**	.13	--	.21	.71**	.39**	--	.13	.64**	.31*
	2. Accuracy		--	.10	-.18		--	-.23	-.28*		--	.16	.13		--	.03	.43*
	3. Intensity			--	-.22			--	.11			--	.15			--	.33**
	4. Avoidance				--				--				--				--

* $p \leq .05$
** $p \leq .01$

Table 52. Intercorrelations Between Measures for Spontaneous Expressions to Highly Unpleasant Odors (Condition 5) by Subject Group as a Function of Nostril Presentation and Valence

		Left Pleasant				Right Pleasant				Left Unpleasant				Right Unpleasant			
Subject Group	Measure	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
LHDs (n = 15)	1. Responsivity	--	-.23	.27	.46	--	-.30	.44	.48	--	.19	.11	.28	--	-.15	.36	-.05
	2. Accuracy		--	.24	-.47		--	.04	-.38		--	-.16	.13		--	-.10	.65**
	3. Intensity			--	-.38			--	.02			--	-.36			--	.-.02
	4. Avoidance				--				--				--				--
RHDs (n = 12)	1. Responsivity	--	.05	.23	.49	--	.34	.28	.04	--	.34	.72**	.66*	--	.46	.33	.40
	2. Accuracy		--	.00	-.27		--	-.04	-.36		--	.78**	.54		--	.25	.47
	3. Intensity			--	-.47			--	.30			--	.75**			--	.02
	4. Avoidance				--				--				--				--
NCs (n = 14)	1. Responsivity	--	.08	.45	.24	--	.50	.35	.45	--	-.08	.41	.34	--	.12	.60*	.30
	2. Accuracy		--	.05	.03		--	.47	.21		--	-.17	.23		--	.44	.36
	3. Intensity			--	-.10			--	.46			--	.44			--	.07
	4. Avoidance				--				--				--				--
All Ss (n = 41)	1. Responsivity	--	-.07	.38*	.33*	--	.19	.40**	.28	--	.15	.43**	.41**	--	.17	.47**	.20
	2. Accuracy		--	.09	-.34*		--	.07	-.07		--	.15	.30		--	.10	.56**
	3. Intensity			--	-.37*			--	.05			--	.13			--	-.05
	4. Avoidance				--				--				--				--

* $p \leq .05$
** $p \leq .01$

responses. A significant correlation also emerged between accuracy and presence of avoidance responses for the LHDs, but only for unpleasant odors presented to the right nostril. When all subjects were taken together, responsivity correlated with intensity regardless of valence and nostril presentation. In addition, responsivity correlated with presence of avoidance responses when odors (both pleasant and unpleasant) were presented to the left nostril. Presence of avoidance responses was related to accuracy in two circumstances: a negative relationship emerged for pleasant odors presented to the left nostril, whereas a positive relationship was found for unpleasant odors presented to the right nostril. Intensity also negatively correlated to presence of avoidance responses for pleasant odors presented to the left nostril.

Intercorrelations for Condition 2. Results of these correlations are shown in Table 53. For pleasant odors, significant correlations emerged between responsivity and intensity for all three groups. In addition, for the NCs, responsiveness and accuracy were significantly related for pleasant odors presented to the right nostril. For unpleasant odors, responsiveness and intensity were also significantly correlated, except in one circumstance for the LHDs (i.e., unpleasant odors presented to the right nostril). In addition, for LHDs and NCs, accuracy and intensity were significantly related when unpleasant odors were presented to the right nostril.

When correlations were completed for all subjects together, significant relationships emerged between responsivity and intensity, and between accuracy and intensity, regardless of valence or nostril presentation. In addition, responsiveness and

accuracy were also significantly related except when unpleasant odors were presented to the left nostril.

Intercorrelations for Condition 3. Results of these correlations are shown in Table 54. When groups were examined individually, only two significant correlations emerged, and this was no greater than that expected by chance. Likewise, the number of significant correlations calculated for all subjects together was not greater than that expected by chance.

Table 53. Intercorrelations Between Measures for Prompted Expressions to Odors (Condition 2) by Subject Group as a Function of Nostril Presentation and Valence

		Left Pleasant			Right Pleasant			Left Unpleasant			Right Unpleasant		
Subject Group	Measure	1	2	3	1	2	3	1	2	3	1	2	3
LHDs (n = 19)	1. Responsivity	--	.27	.54*	--	.31	.65**	--	-.19	.47*	--	.04	.42
	2. Accuracy		--	.30		--	.36		--	.34		--	.48*
	3. Intensity			--			--			--			--
RHDs (n = 21)	1. Responsivity	--	.45*	.51*	--	.25	.60**	--	.24	.72**	--	.39	.83**
	2. Accuracy		--	.22		--	.18		--	.28		--	.25
	3. Intensity			--			--			--			--
NCs (n = 18)	1. Responsivity	--	.28	.48*	--	.54*	.60*	--	.33	.50*	--	.25	.61**
	2. Accuracy		--	.38		--	.01		--	.18		--	.48*
	3. Intensity			--			--			--			--
All Ss (n = 58)	1. Responsivity	--	.39**	.45**	--	.44**	.61**	--	.15	.59**	--	.27*	.77**
	2. Accuracy		--	.29*		--	.26*		--	.31*		--	.33**
	3. Intensity			--			--			--			--

* $p \leq .05$
** $p \leq .01$

Table 54. Intercorrelations Between Measures for Subjective Ratings to Odors (Condition 3) by Subject Group as a Function of Nostril Presentation and Valence

		Left Pleasant			Right Pleasant			Left Unpleasant			Right Unpleasant		
Subject Group	Measure	1	2	3	1	2	3	1	2	3	1	2	3
LHDs (n = 19)	1. Responsivity	--	.02	.23	--	.19	.29	--	-.03	-.33	--	.13	.27
	2. Accuracy		--	.20		--	-.00		--	.35		--	.41*
	3. Intensity			--			--			--			--
RHDs (n = 20	1. Responsivity	--	-.19	-.51*	--	.05	.36	--	-.32	-.09	--	-.24	-.16
	2. Accuracy		--	.42		--	.17		--	.05		--	.22
	3. Intensity			--			--			--			--
NCs (n = 18)	1. Responsivity	--	.25	.24	--	.20	-.14	--	-.20	.07	--	.02	.12
	2. Accuracy		--	.31		--	.10		--	.29		--	.28
	3. Intensity			--			--			--			--
All Ss (n = 57	1. Responsivity	--	.04	-.07	--	.12	.19	--	-.18	-.18	--	-.02	.09
	2. Accuracy		--	.31*		--	.11		--	.21		--	.27*
	3. Intensity			--			--			--			--

* $p \leq .05$
** $p \leq .01$

DISCUSSION

This study examined several components of emotional processing, including hedonic and emotional facial expression, hedonic perception/experience, and affective behaviors. The first two components were examined to determine whether or not the findings were consistent with either of two theories regarding hemispheric specialization of emotional processing (i.e., the valence hypothesis or the right hemisphere hypothesis). In addition, affective behaviors (e.g., choice behaviors and avoidance responses) were observed and compared amongst the three group of subjects to ascertain if hemispheric asymmetries existed for such behaviors, including whether or not there was a right hemisphere predominance in avoidant/withdrawal action tendencies. For all conditions using odorants, the role of intrahemispheric effects was explored. Valence effects for these analyses are also discussed. Then, the relationship among experimental parameters are considered. Finally, the relationship between hedonic experience and expression was explored, in order to evaluate whether these are interrelated or separate components of the emotional system.

Facial Expression

Spontaneous Facial Expressions Elicited by Odors. Evaluation of these facial expressions indicated that LHDs, RHDs and NCs were rated similarly in terms of hedonic responsivity, accuracy and intensity of facial expression. No group differences emerged even when highly unpleasant odors were used to elicit expressions.

In part, the lack of findings for spontaneous expressions in the present study may be due to a paucity of facial responses to odors in general. Qualitative examination of the videotaped responses in the spontaneous expression conditions showed that there was in general little facial movement. This is supported by the judges' ratings of intensity for facial expressions, which were at the lower end of the rating scale, (i.e., mean intensity ratings were between 1 and 2 on the 11-point rating scale). Indeed, others have found minimal spontaneous facial movement to odors (Gilbert et al., 1987). The lack of spontaneous facial responses to odors limited the utility of these conditions to evaluate the two neuropsychological theories of emotion, yet the spontaneous expression condition did yield intriguing information regarding group differences in avoidance responses (discussed below).

The lack of findings in the current study are in contrast to findings of others (Borod et al., 1985, 1986, 1988; Blonder et al., 1993; Buck & Duffy, 1980; Martin et al., 1990; Weddell et al., 1988), where group differences in spontaneous emotional expressions were reported. In the majority of those studies, facial expressions of RHDs were less expressive than the healthy control subjects, as indicated by a number of different measures (e.g., appropriateness). Most of those studies used slides to induce emotional reactions in the subjects. Other methods used to induce facial expressions included examination of responses to a stressful neuropsychological task (e.g., the Wisconsin Card Sorting Test) (Weddell et al., 1988) or to responses produced during conversation (Blonder et al., 1993). One possibility is that the differences between the current and previous studies may be due to the way in which expressions were induced

(e.g., to verbal questioning, to visually provocative material, or to odorants). The majority of studies used methods which rely heavily upon cognitive processing to appreciate the hedonic properties of the stimuli, whereas perhaps odorants are less cognitively mediated. Yet, some investigators (e.g., Mammacuri et al., 1988) have used affective slides and did not find any significant group differences either when facial displays were viewed by naïve raters or when an analytical rating procedure (e.g., FACS) was used. Therefore, it is not clear if the differences in outcome between the different studies are related to differences in the patient groups studied, to the manner in which affective responses were elicited in the participants, or to the procedures used in evaluating facial expressions. The current study does not permit resolution of this issue, so a definitive conclusion regarding the lateralization of spontaneous hedonic facial expressions awaits further investigation.

Prompted Facial Expressions to Odors. When facial responses to odors were prompted from the different group of participants, no consistent set of group differences emerged. The findings from this condition were of interest, as such voluntary expressions are thought to be elicited via a cortical, rather than subcortical, route (Borod & Koff, 1984; Wilson-Pauwells et al., 1988; Van Gelder & Van Gelder, 1990). Perhaps the clearest result of this condition was that both LHDs and RHDs were, in general, capable of expressing their experience of an odor by producing facial responses, and did so in a manner fairly similar to the control group. The group differences that did occur were not especially supportive of the two lateralization hypotheses being considered. The statistical differences observed (the LHDs' expressions being rated as less responsive than NCs for

odors given to the right nostril, the RHDs' expressions being rated as being less accurate than NCs for pleasant odorants administered to the right nostril, and the LHDs' expressions being less intense for unpleasants than pleasants) in fact run contrary to the valence hypothesis, and are mixed in terms of their agreement with the right hemisphere hypothesis.

In previous studies that examined posed emotional facial expressions, the majority asked subjects to pose six different emotions, either to verbal command or to imitation, and then analyzed expressions using either the FACS coding system or raters. In such studies, several investigators found significant group differences, and in general, RHDs performed more poorly as a function of specific emotions (Borod et al., 1986, 1988, 1990; Bruyer, 1981; Kent et al., 1988), and also as a function of the perceiver's rating of emotional valence (positive vs negative emotion) of the facial expression (Kent et al. 1988).

The current study differed from past studies in that participants were asked to deliberately pose their experience (i.e., to indicate on their face how the odor made them feel). There are no published studies to date where individuals with neurological damage were asked to pose expressions indicative of their experiential state. The lack of consistent group differences in prompted expressions to odors suggests that: a) overall, participants with unilateral brain lesions can convey pleasant and unpleasant states via facial expressions in a manner similar to healthy subjects; and/or b) lateralization of emotion is not at the dimension of hedonics (pleasantness/unpleasantness), but perhaps occurs along some other level or dimension of emotional processing. As subjects in the

current study were asked to pose pleasant and unpleasant expressions without using odors, to pose expressions conveying discrete emotions, and also to make subjective ratings of odors, these explanations are explored further below.

Posed Hedonic Expressions. Unique to this study, subjects were asked to deliberately pose pleasant and unpleasant expressions. Here, no group or interaction effects between group and valence emerged. Accuracy scores were higher for this task than for prompted expression to odors or for expressions of six discrete emotions, indicating that it was easier for raters to determine hedonic/emotional category (and/or for subjects to pose these expressions) in this task than in the other expression conditions. This may account for the lack of group differences in the posed hedonic expression condition. Nevertheless, no hemispheric differences as a function of hedonicity (or valence) emerged regardless of whether expressions were prompted to odors or were elicited by verbal commands.

Posed Expressions to Six Discrete Emotions. Group differences did emerge for facial expressions posed to discrete emotions. Here, when non-emotional facial movement factors were appropriately controlled for, the findings for ratings of accuracy, confidence ratings in category judgments, and intensity suggested that participants with right hemisphere lesions were less accurate and made less intense expressions than NCs and/or LHDs. When specific emotions were grouped to examine valence effects, valence did not modify the effects seen for accuracy and intensity.

Analyses of confidence ratings suggested that raters were less confident in judgments of emotional category for the RHD subjects. This appears to be due to RHDs'

general difficulty in posing emotional expressions, rather than to the RHDs posing a different expression than the one instructed, based on covariate analyses controlling for accuracy. Valence did play a role in confidence ratings, but the findings observed were not consistent with the valence hypothesis. Specifically, the valence effects seen indicated that judges were less confident in their rating of the positive expressions for RHDs, and less confident in ratings of negative emotions for both RHDs and LHDs. However, when accuracy of pose was taken into account in a subsequent analysis for confidence ratings, confidence ratings were significantly lower only for the RHD group in comparison to the NC group. Overall, when effects of Group and Valence were examined, the findings for facial expressions produced to six different emotions implicate the role of the right hemisphere in emotional facial expression, in keeping with findings by others (Borod et al., 1990; Bruyer, 1981; Kent et al., 1988; Kolb & Taylor, 1990; Weddell et al., 1990).

Additional analyses were conducted to determine whether group differences emerged as a function of specific emotions (see Appendix 6). The findings for posed facial expressions to six discrete emotions showed that, when the degree of buccofacial apraxia was taken into account, RHDs were overall less able to produce appropriate emotional facial expressions than NCs, and that this was not specific for any single, basic emotion. In terms of confidence and intensity ratings, there were some significant interactions between group and emotional category, but no systematic effects as a function of emotion emerged for the two rating measures. Mostly, these findings indicated that raters were less confident in rating RHDs' expressions and that these expressions were less intense than NCs and/or LHDs. Thus, unlike expressions produced to odors as well

as posed hedonic expressions, findings from facial expressions to six discrete emotions supported the right hemisphere hypothesis.

Comparisons Among the Facial Expression Conditions

The differences in the findings between expressions elicited by odors and posed facial expressions to six discrete emotions in the current study perhaps suggest differential involvement of two neuroanatomical pathways by which emotional meaning/expression can be acquired or elicited – a cortical versus subcortical route (see e.g., LeDoux, 1993; Gainotti, Caltagirone & Zoccolotti, 1993; Tucker 1993). Sensory information presumably acquires emotional meaning via both routes. Perhaps odors are more "experiential" in nature than other types of affective stimuli, and are therefore processed preferentially by a subcortical route versus the route used to process the verbal commands used to elicit expressions to the six discrete emotions. This is supported by neuroanatomical studies indicating that olfactory processing involves primarily subcortical and limbic structures (Brodal, 1981; Eslinger, Damasio & Van Hoesen, 1982; McLean & Shipley, 1992).

Although voluntary expressions were produced in tasks eliciting facial responses to odors and emotional facial expressions, and these expressions are presumably cortically mediated, perhaps expressions produced to odorants are mediated to a greater extent by the subcortical route, and this therefore explains the lack of hemispheric asymmetry. This subcortical route may be related either to the way in which the information is acquired (sensory/perceptual) or due to differences in the modulation of motoric output (expression). This latter statement would then suggest that prompted expressions elicited

by odors are perhaps not purely cortically mediated, since odors are experiential and stimulate subcortical structures, even though people are intentionally posing an expression. To further explore differential processing by a cortical versus subcortical route as a function of elicitation method, a similar study comparing expressions evoked in subjects with subcortical-only versus cortical-only lesions might be useful.

Yet, this explanation does not entirely account for all results of the current study regarding facial expressions, as no group differences emerged for posed hedonic expressions elicited in response to verbal command. If the cortical/subcortical explanation provided above is operative, then perhaps, hedonic facial expressions are subcortically mediated regardless of the elicitation method used. For example, Steiner (1979) proposed a "reflexive-hedonic model" of facial responses to odors, where these responses are biologically hard-wired, with facial behaviors reflecting the hedonic evaluation of the odor in a reflex-type of response. Such reflex-like expressions were produced in a hydroanecephalic infant lacking cortical forebrain structures (Steiner, 1977; 1979). This is not to say that such hedonic expressions are not also modulated by cortical mechanisms (i.e., voluntary control), as suggested in several studies with healthy subjects (e.g., Gilbert et al., 1987; Kraut, 1982; Soussignan & Schaal, 1996), but rather, that there is substantial involvement of subcortical processing which plays an important role in producing such expressions.

No compelling group effects emerged for prompted expressions to odors or for posed hedonic expressions, conditions where the hedonic dimension of emotional processing was emphasized. Substantive group differences were found only when

participants were asked to pose discrete emotional facial expressions. Thus, the findings from the current study perhaps suggest that the level at which lateralization of hedonic and emotional facial expressions occurs is not at the fundamental level of hedonicity (pleasantness/unpleasantness). Posing expressions of six discrete emotions may be a more complex task than posing a pleasant or unpleasant expression, or posing a pleasant or unpleasant odor experience. Evidence from this, as well as other studies, indicated that RHDs have difficulties in posing discrete emotional expressions. Studies by others implicate the importance of right hemisphere functions in the appreciation of emotional stimuli (e.g., Borod et al., 1986; Bowers et al., 1985; Etcoff, 1984; Ley & Strauss, 1986). Perhaps, then, the right hemisphere plays a greater role in more complex emotional tasks, and/or in more symbolic aspects of affective behaviors. This includes the ability to perceive and/or identify emotions, as well as the ability to express emotions via the facial channel. Therefore, perhaps the right hemisphere contains an emotional lexicon, linking specific facial expression patterns to particular emotional labels or concepts (e.g., Bowers et al., 1993). Given that the majority of subjects in this study had lesions involving cortical regions, it seems that right neocortical regions are perhaps more involved in "higher level" affective processing. The idea of a cortically-based affective network has been discussed by others in terms of the perception, as well as the expression, of emotion (see e.g., Borod, 1993; Bowers et al., 1993). More specifically, Adolphs, Damasio, Tranel & Damasio (1996) suggested that impaired recognition of emotional facial expressions observed in patients with right cortical lesions may be due to a defect in the concept retrieval system blocking the access of information regarding experiential states

and factual knowledge associated with certain types of facial expressions. If so, then perhaps the more complex emotional task (the discrete emotions task) relies more heavily on such cortical modules, in contrast to prompted expressions to odors as well as posed hedonic expressions. For responses to odorants, perhaps more information is available to individuals with right cortical lesions, since knowledge of the odor experience is relatively intact. For posed hedonic expressions, perhaps pleasant and unpleasant experience (feeling good vs feeling bad) is a more fundamental to emotional states (in a sense, more basic) than discrete emotional emotions, and thus the availability of multiple, intact cortical modules is not as necessary for expressing such basic hedonic states.

An alternative explanation for the discrepancies between the two elicitation methods is related to qualitative differences between hedonic and emotional expressions. It may be that sensory hedonics, such as the experience produced by smell or taste, is separate and dissociable from affective hedonics. Thus, one can detect that an odor or taste is pleasant or unpleasant, and although it is possible for this to influence mood and other affective behaviors, it is not necessarily the case that one's affective state is altered by this sensory experience. Thus, when prompted to produce expressions related to olfactory sensory experience, all subjects, regardless of the presence or absence of lesions, can properly elicit expressions related to this experience, whereas the same brain lesions alter or impair "higher-level" affective functions. Thus, the neural system (or systems) related to sensory hedonics may be dissociable from the system(s) related to affective hedonics or affective processes.

It is important to note that the lack of compelling group differences emerging for the odor and posed hedonic expression tasks is not due to the absence of sensory, cognitive, or motor impairments in the RHD and LHD groups. Individuals with brain lesions performed more poorly than healthy controls on several screening and facial movement tasks (see Appendix 5). Reductions in performance were seen on the olfactory identification task for the LHDs and RHDs relative to NCs. Facial paralysis was present in both brain lesion groups, and the LHD group demonstrated significant difficulties with buccofacial praxis relative to RHDs and NCs. Furthermore, the RHDs performed more poorly on the Attention Scale of the Dementia Rating Scale than controls, whereas the LHDs had greater difficulty on the Memory Scale of the Dementia Rating Scale relative to controls.

Intrahemispheric Effects for Expressions Evoked by Odors

Analyses for both spontaneous and prompted expressions to odors indicated that, overall, site of lesion had no effect on expressions elicited in response to odors. However, there were several significant interaction effects involving lesion site for several measures. In order to determine if any systematic effects emerged for such measures, the pertinent interactions (those which were significant or indicative of a trend) were compared across measures and across spontaneous and prompted expression conditions. Table 55 lists such interactions, as well as relative responses based on mean values for the different lesion site groups. Table 55 can be compared to Table 25, which outlined predicted effects of lesions at particular intrahemispheric sites.

As shown in Table 55, for both spontaneous and prompted expressions to odors, the most consistent finding to emerge was that LHDs with posterior lesions tended to be rated as making expressions which were more hedonically responsive and more intense than RHDs with posterior lesions, although this post-hoc comparison did not always yield significant differences between these groups. These findings are similar to those in a study by Buck and Duffy (1981), where individuals with left hemisphere lesions were more

Table 55. Summary of Findings Related to Intrahemispheric Effects For Facial Expressions To Odors

Condition (and Interaction)	Measure and Level	Relative performance (based on mean values) found for each subgroup***
Spontaneous Expressions		
Responsivity (G x LS x V x N)*		
	Right Pleasant	RHDp < RHDa+p < LHDa+p < LHDp
	Right Unpleasant	RHDp < LHDa+p < RHDa+p < LHDp
	Left Pleasant	RHDp < LHDa+p < RHDa+p < LHDp
	Left Unpleasant	RHDp < RHDa+p < LHDa+p < LHDp
Intensity (G x LS x V)*		
	Pleasant	LHDa+p < RHDp < RHDa+p < LHDp
	Unpleasant	RHDp < LHDa+p < RHDa+p < LHDp
Prompted Expressions		
Intensity (G x LS x V x N)*		
	Right Pleasant	RHDa+p < RHDp < LHDa+p < LHDp
	Right Unpleasant	LHDa+p < LHDp < RHDp < RHDa+p
	Left Pleasant	RHDp < RHDa+p < LHDa+p < LHDp
	Left Unpleasant	LHDa+p < LHDp < RHDp < RHDa+p
Responsivity (G x LS x V x N)**		
	Right Pleasant	LHDa+p < RHDp < RHDa+p < LHDp
	Right Unpleasant	LHDa+p < RHDp < LHDp < RHDa+p
	Left Pleasant	RHDp < LHDp < LHDa+p < RHDa+p
	Left Unpleasant	LHDa+p < RHDp < LHDp < RHDa+p

Abbreviations: G = Group; LS = Lesion Site; V = Valence; N = Nostril; RHDa+p = RHDs with anterior plus posterior lesions; RHDp = RHDs with posterior only lesions; LHDa+p = LHDs with anterior plus posterior lesions; LHDp = LHDs with posterior only lesions.

* = significant ($p \leq .05$) interaction; ** = trend ($p < .10$) for interaction.

***n.b. Relative mean values for the different lesion site subgroups do not indicate significant differences in performance between these lesion subgroups by post hoc comparisons.

expressive in spontaneous reactions to emotional slides, in comparison to either healthy controls or subjects with right-hemisphere lesions, especially to slides which were unpleasant in nature. Similarly, Kent et al. (1988) found that LBDs posed expressions more intensely than RBDs and NCs. Buck and Duffy (1980) proposed that perhaps the right hemisphere played a predominant role in non-verbal expressions, withthe left hemisphere acting to modulate or inhibit right hemisphere functions. This same explanation may be tentatively applied to the current study. As previously indicated, a lack of findings in the right-hemisphere group may be due to the fact that few spontaneous expressions were reliably elicited by odorants. Yet, it is of interest that participants with left posterior cortical lesions appeared to be more responsive than the other subgroups of subjects with brain lesions.

Heller (1990, 1993) described the importance of posterior brain regions for the dimension of arousal in emotional processing. Specifically, she speculates that the modulation of the autonomic and behavioral arousal system involves right parietotemporal regions. Higher activation in this area is associated with higher autonomic arousal, and decreased activation with lower arousal. If relative levels of arousal play a role in facial responses to odors, perhaps posterior lesions in the right hemisphere result in lower levels of arousal and thus, less expressive facial responses when compared to performance in individuals with posterior lesions in the left hemisphere.

There were no consistent effects to emerge as a function of anterior involvement of lesions, that is, subjects with lesions involving anterior and posterior regions did not

perform more poorly when compared to posterior only subgroups. Thus, the hypothesis that anterior regions play a greater role in expressive behavior was not borne out.

Hedonic Experience

Group Differences. Also of interest in the current study were subjective ratings of the odors, which were used as a measure of hedonic experience. One problem in conceptualizing this measure as being "experiential" is that there is obviously a perceptual and a sensory component in processing hedonic olfactory information; thus, this condition is perhaps better thought of as being one which is both sensory and experiential in nature.

The only significant group difference to emerge for subjective ratings of odors was for intensity, and these findings supported the right hemisphere hypothesis. Here, RHDs rated odors as being less hedonically intense than NCs when odors were presented to the right nostril. No significant group differences emerged when odors were presented to the left nostril.

It may be that this finding is due to lesion effects on general olfactory abilities. In studies examining hemispheric asymmetries in olfactory processing, several investigators have found differential nostril effects as a function of side of lesion (Eskenazi et al., 1983; Martinez et al., 1993; Zatorre & Jones-Gottman, 1991). When measures of subjective ratings of odors were correlated to general olfactory ability, positive correlations were obtained for several of the measures. To determine whether the difference seen in the current study was related to general olfactory ability, performance on the Smell Identification Test was controlled for by using it as a covariate; findings from these

analyses were no different from those reported above. In addition, if general olfactory ability was related to this finding, then one would expect significant differences to emerge between LHDs and NCs when odors were presented to the left nostril, as LHDs' performance on the Smell Identification Test was different from healthy controls for odorants presented to the left nostril (this effect was a trend, as reported in Appendix 5). Such a group by nostril effect was not found for hedonic intensity.

The finding for the RHD group regarding subjective ratings of odors is not consistent with other studies examining experiential aspects of emotion. Several studies indicate that RHD subjects rate themselves as experiencing emotion as intensely as do LHD and healthy control subjects (see Bowers et al., 1993; Cimino, Verfaellie, Bowers & Heilman, 1991; Meadows & Kaplan, 1994). Methodological differences exist between studies examining emotional experience and the current study, related to the modality or means by which hedonic/emotional experience was elicited. For example, in the Cimino et al. (1991) study, subjects were asked to rate how emotionally significant an autobiographical event expressed was when asked to describe the event. Meadows and Kaplan (1994) asked subjects to describe affective slides and to indicate how the slides made them feel. Perhaps the findings of the current study (i.e., group differences in hedonic intensity ratings) provide a more sensitive index of hedonic experience than these other methods, and thus can detect subtle hemispheric differences in this component of emotional processing. Clearly, more studies are needed to clarify differences between findings regarding hemispheric differences in emotional versus hedonic experience.

Intrahemispheric Effects. When lesion site was considered as a factor in these analyses, no significant effects emerged among the four lesion subgroups for ratings of responsivity, accuracy or intensity, although examination of mean values for the measures were lower for the RHD anterior plus posterior group (see Results, Table 36). Within-group comparisons revealed significant differences primarily for RHD subjects with anterior plus posterior lesions, where these subjects' were less responsive and accurate in their ratings of the pleasant odors in comparison to unpleasant odors (for accuracy, this effect emerged only for odors presented to the right nostril). Using this smaller sample of subjects, the LHDs rated odors as being more intense than the RHDs. Overall, the effects of lesion site within the cerebral hemisphere were not very compelling regarding experiential ratings. Perhaps more definitive conclusions regarding intrahemispheric effects for hedonic experience would emerge by including individuals with anterior lesions only, such as brain tumor cases, but this awaits further investigation.

Behavioral Measures

Behavioral Choice Measure. One condition included in the current study was to ascertain if group differences would emerge in terms of the number of pleasant odors selected when subjects were asked to choose between pleasant and unpleasant odors. Here, there was a tendency for LHDs to choose fewer pleasant odors than the other two groups, even when controlling for general olfactory abilities. When intrahemispheric effects were examined, the trend which emerged suggested that LHDs with anterior plus

posterior lesions chose fewer pleasant odors when odorants were presented to the left in comparison to the right nostril.

This finding tends to provide partial support for the valence hypothesis, rather than the right hemisphere hypothesis. If the left hemisphere is more involved in evaluating, experiencing and expressing positive, or pleasant, affective information, then the greatest difference expected to emerge using monorhinic presentation would be for left nostril presentation to subjects with left hemisphere lesions involving anterior plus posterior cortical structures. This finding suggests that perhaps this group may be less able to anticipate the consequences of their choice behavior than the other groups, given that the accuracy ratings for odors (i.e., subjective ratings of odors) for this group were equivalent to the other lesion subgroups. The importance of frontal regions in goal-directed behavior has been discussed by several investigators (e.g., Damasio & Anderson, 1993; Luria, 1966; Stuss & Benson, 1987). Frontal regions have been described as serving inhibitory functions -- suppressing dominant action tendencies in favor of more goal-appropriate behavior. The prefrontal cortex is also involved in planning, requiring the prioritization of goals to constrain and guide behavior. Given the extensive interconnections between limbic and prefrontal cortical structures (Barbas, 1995), experiential states (and drives) may serve to guide an organism's behavior. Therefore, if the left hemisphere is dominant in evaluating pleasant emotional stimuli and modulating positive states, then one would expect left frontal lesions to impair goal-directed activities based upon such affective or hedonic states.

The finding observed for choice behaviors cannot be attributed to differences in general olfactory identification abilities, as there were no significant main or interaction effects when performance on the Smell Identification Test was examined as a function of Group, Lesion Site and Nostril (see Appendix 5, Table 61). Another possible reason for group differences may be due to language difficulties, but this is unlikely, given that the Group by Lesion Site interaction was not significant. Here, one would expect that LHDs with anterior plus posterior lesions would perform more poorly than the other subgroups regardless of nostril presentation. Nevertheless, Spearman correlations were computed for each of the four subgroups to determine the relationship between performance on the two subtests of the Boston Diagnostic Aphasia Examination (e.g., Commands and Reading Sentences and Paragraphs) and the number of pleasant odors chosen for each nostril presentation. Of the 16 correlations computed (4 X 4 groups), only one correlation was significant. This was for the right anterior plus posterior group, where reading performance was positively correlated to number of pleasant odors chosen for odor pairs presented to the right nostril (rho = .77). Thus, the effect observed for the behavioral choice measure appears to be unrelated to deficits in comprehension.

Withdrawal/Avoidant Responses. A final behavior of interest was the avoidant responses exhibited in the three groups of subjects. According to the approach/withdrawal hypothesis, the right hemisphere is predominant in withdrawal responses, so it was predicted that RHDs would be less avoidant. Although this result was not found, it will be considered how the findings for avoidant responses relate to the approach/withdrawal hypothesis. In fact, the LHD group exhibited more avoidant

responses than RHDs and NCs (Tables 43 and 44). When performance was examined on an individual basis, the LHD group exhibited the most avoidant responses (42% of the group made at least one avoidant response as judged by the majority of the raters), while the RHD and NC groups had substantially fewer responders (19% and 17% respectively). This finding is consistent with the idea that the left hemisphere provides an inhibitory influence over right-hemisphere mediated withdrawal, and that the LHD group made more avoidant responses because of decreased inhibitory control. The idea that the left hemisphere provides inhibitory influence on withdrawal and related affective behaviors via contralateral disinhibition draws support from a number of other studies.

One behavior is exaggerated affective responses or catastrophic reactions following left-hemisphere lesions (Gainotti, 1972; Hecaen, 1962; Starkstein et al., 1993). Indeed, several researchers have proposed that the left hemisphere plays a predominant role in emotional control (Gainotti et al., 1993). Another example is where supratentorial vascular lesions resulting in hemiplegia may be releasing withdrawal-like behaviors, evidenced by enhancement of the audiogenic startle reflex on the plegic side (Voordecker, Mavroudakis, Blecic, Hildebrand, & Zegers de Beyl, 1997). Although this study did not specifically address a laterality bias, the majority of subjects in the small sample had left-hemisphere cortical or white matter lesions.

Further evidence arises from EEG studies examining laterality effects related to disposition, mood and action tendencies in healthy subjects. Individual differences in asymmetric anterior activation have been associated with differences in dispositional and mood differences (for review, see Davidson, 1993). Thus, people with increased right-sided anterior activation may be more vulnerable to emotions, moods, and

psychopathology (e.g., anxiety disorders) associated with withdrawal (see e.g., Davidson et al., 1990; Sutton & Davidson, 1997). Davidson (1993) cites a study by Davidson, Finman, Straus & Kagan (1992) where toddlers who are shy in approaching novel objects or people show decreased left frontal activation in comparison to non-reticent children. Such studies are particularly relevant to the current study, as well as perhaps explaining the variability seen regarding presence of avoidant responses observed in the LHD group in comparison to the RHDs and NCs. Individual differences in affective style may account for the variability within the LHD group, where the interhemispheric effects of the brain lesion interact with premorbid individual differences in hemispheric asymmetries, personality, and temperament. This might explain why left-sided damage alone is not solely responsible for an increased propensity of withdrawal behaviors. Perhaps, the individuals with left-sided lesions who were more likely to demonstrate avoidant responses in the current study were also those who had greater right anterior activation prior to their stroke and tended to have dispositions which were more prone to negative affect and withdrawal behavior. It would be interesting to examine premorbid personality factors in future studies of withdrawal action tendencies in individuals with unilateral lesions to explore this relationship.

Given that these EEG studies suggest the importance of anterior regions in approach-withdrawal asymmetries (for review, see Davidson, 1995), intrahemispheric effects were examined in the current study to ascertain whether left or right anterior regions were more influential in producing avoidant or withdrawal responses in subjects with unilateral lesions. No significant effect was seen as a function of Group and Lesion Site. However, when odors were presented to the right nostril, ratings of avoidance

response were greater in participants with lesions involving anterior and posterior regions in comparison to those with only posterior lesions (see Tables 46 and 47). No group differences emerged for odors presented to the left nostril. These findings may argue for the role of anterior regions, in general (regardless of side of lesion), in producing enhanced withdrawal responses. However, it may be that lesions are larger in the subset of subjects with anterior plus posterior lesions, and thus, larger lesions are more likely to result in disinhibition of behaviors, due to a lack of neocortical control. Nevertheless, the fact that more avoidant responses were observed to odors with right nostril presentations suggests that the right hemisphere may have a predominant role in producing this effect, as olfactory pathways are predominantly ipsilateral. Therefore, as alluded to earlier, left hemispheric lesions seem to release the right hemisphere's ability to produce avoidant responses.

The failure to see a decrease in withdrawal behaviors of RHDs, in comparison to healthy controls, is the aspect of these findings that least supports the approach/withdrawal hypothesis. One possible explanation is a "floor" effect, given the rare occurrence of such behaviors. Although 19% and 17% of the members of these two groups had at least one "consensus" avoidant response (i.e. at least 5 of 7 raters noted such), neither of these groups made a great number of avoidant responses, and so a decline in number may not have been easily detected. If such responses have a low base rate of occurrence, differences between RHDs and NCs may only be detected with a larger sample.

The above explanations for the findings regarding withdrawal responses have focused upon hemispheric asymmetries in action dispositions. However, another

interpretation of these results is that the withdrawal response is an indicator of arousal. Several researchers have attempted to define the differences between arousal and activation (see e.g., Heilman & Watson, 1989; McGuinness & Pribram, 1980; Tucker & Williamson, 1984). Activation influences the premotor and motor systems, and refers to initiation of movement, whereas arousal is described as producing more widespread excitation of the nervous system, particularly influencing sensory and cognitive systems. Physiological measures, such as skin conductance and heart rate, have been used as measures of arousal. Using such measures, hemispheric asymmetries in arousal have been reported in several studies, with consistent findings indicating that right hemisphere lesions result in reductions in arousal (Caltigirone, Zoccolotti, Originale, Daniele & Mamucari, 1989; Heilman, Schwartz & Watson, 1978; Meadows & Kaplan, 1994), with several studies reporting hyperarousal following left hemisphere lesions (e.g., Caltigarone et al., 1989; Heilman et al., 1978). Such studies suggest that the left hemisphere exerts inhibitory control on arousal mechanisms mediated by the right hemisphere. Thus, a similar mechanism as that described previously (e.g., Davidson, 1984), suggests that increased avoidance responses seen after left hemisphere lesions are due to increased levels of arousal following left-hemisphere damage. Whether the hemispheric differences observed in the current study regarding the occurrence of avoidant responses are due to differences in arousal or activation cannot be determined by these findings. However, the finding of enhanced withdrawal responses in individuals with LHD is consistent with an inhibitory role of left cortical regions in both arousal and a variety of other affective processes.

The finding for enhanced withdrawal responses to odors has a potential clinical application. Given that exaggerated affective responses (e.g., catastrophic reactions) can occur following hemispheric lesions, perhaps withdrawal responses to odors can be used as a relatively innocuous and easy way to predict which individuals may be susceptible to such reactions. A scale has recently been developed to measure catastrophic reactions (Starkstein et al., 1993), and this scale could be used to determine whether or not individuals who are prone to having a catastrophic reaction also have enhanced withdrawal responses to odors. If odors can indeed predict this type of a reaction, a simple test using odors can be developed for use with individuals shortly after stroke to determine the need for early intervention of this unpleasant behavioral response.

Valence Effects

In the current study, an attempt was made to match the pleasant and unpleasant odors in terms of hedonic intensity. Nevertheless, significant effects (or trends) were seen for almost all parameters examining hedonic expression and experience to odors, with the exception of subjective ratings of hedonic accuracy. Unpleasant odors consistently produced greater effects than pleasant odors. Similarly, Borod et al. (1988) found spontaneous expressions to be rated as being more responsive to negative than to positive affective slides. Likewise, a number of studies using odors have found an increased effect for unpleasant odors in modulating affective responses (Ehrlichman, 1987; Ehrlichman et al., 1995; Gilbert et al, 1987; Miltner et al., 1994). A possible explanation for this greater effect produced by negative or unpleasant affective stimuli is the significance such stimuli

have on survival. This may be especially important in terms of olfactory hedonicity, as unpleasant odors can indicate unhealthy food or environments. Thus, survival depends upon the organisms ability to quickly evaluate and respond to negative stimuli, and this alacrity is probably not as significant when responding to positive stimuli.

Interestingly, when a subset of emotions was examined to determine valence effects for voluntary facial expressions for six emotions, ratings of expressions were greater for positive, relative to negative emotions. One difficulty with this analysis was that only one emotion (happiness) was used as the positive emotion, whereas mean values from 3 negative emotions (fear, disgust, sadness) were used to explore effects of negatively-valenced emotions. Yet, this findings is similar to that reported in other studies of posed facial expressions. For example, posed expressions were rated as being more intense for positive than for negative expressions in healthy controls and subjects with unilateral lesions (Borod et al., 1988; Kent et al., 1988). Posed expressions of happiness were reported to be easier to produce by subjects with unilateral lesions (and healthy controls) in comparison to five other emotions (sadness, anger, fear, disgust, surprise) (Caltagirone et al., 1989). Perhaps, posed expressions of happiness (e.g., smiles) are "rehearsed" more often in daily life, due to social display rules (e.g., Ekman, 1984). For example, subjects may show expressions (e.g., a "grin and bear it" smile) which are not truly felt, but which are often more socially appropriate.

Relationship Among Experimental Measures

The relationship among the dependent measures for each experimental condition was examined. A number of significant relationships were found for the expression conditions but not for the subjective ratings of odors.

When the relationship between facial expression measures was examined, for the most part, few of the measures within each group were significantly related to each other for the spontaneous expression conditions (shown in Tables 51 and 52). When relationships emerged, it was most often between responsivity and intensity. This is consistent with several other studies examining emotional processing (Borod et al., 1988; Grunwald et al., 1997). A greater number of significant relationships emerged between measures when unpleasant odors were presented than during presentation of pleasant odors. As pointed out by Borod et al. (1988), the relationship between responsivity and intensity may reflect an underlying dimension such as arousal; in the current study, perhaps unpleasant odors are more arousing than pleasant odors. For the prompted expressions, in almost all instances, significant relationships emerged between responsivity and intensity (Table 53). This was expected, as raters were instructed to base their ratings of hedonic quality of the odor upon the facial expression of the subject. More intense expressions provide more information upon which raters had to determine their judgment of hedonic quality.

In contrast to the expression conditions, few significant relationships were found between measures for subjective ratings of odors (Table 54). Thus, these measures are not strongly related to each other. Perhaps no significant relationships emerged for

intensity because of the way in which odorants were selected for use in the current study. Odors (and odorant concentrations) were only selected if 80% of the individuals from the pilot study accurately classified the odors. Thus, although some individuals may find the odors more intense than other individuals, the majority of participants could accurately categorize the odors.

Relationship Between Hedonic Experience and Expression

This study allowed for the investigation of the relationship between intensity of experiential and expression ratings to determine the coherence between these two components of emotional processing in participants with RHD or LHD, as well as in healthy controls. The relationship between these components of emotional processing is important, in that this approach raises the issue as to whether single or multiple brain substrates are involved in emotional processing (see e.g., Borod, 1993a). Such analyses allow the investigator to determine if these components are interrelated or dissociated in one group of subjects versus another.

For the current study, a normalization procedure was done in order to increase the power of the statistical analysis used. When intensity of subjective ratings were compared to intensity of the spontaneous expression produced to each odor, there was a tendency for these components to be related only in the healthy subjects for unpleasant odors. The coherence between these components (i.e., experience and expression) has been reported in a number of other studies with healthy subjects examining intensity of subjective experience of various stimuli (i.e., odors, painful shock, and affective visual material) and

spontaneous facial responses (see e.g., Ekman, Friesen & Ancoli, 1980; Kraut, 1982; Lanzetta, Cartwright-Smith & Kleck, 1976; Rosenberg & Ekman, 1994; Zuckerman, Klorman, Larrance & Spiegel, 1981). The lack of a relationship between spontaneous facial responses and subjective ratings in the LHD and RHD group perhaps suggests a dissociation between these processing modes in individuals with brain lesions, but given the weak relationship seen in the control group, this interpretation is extremely tentative.

For prompted expressions, where participants were asked to indicate how the odor made them feel via a facial response, the relationship between intensity ratings for subjective experience and facial expressions for unpleasant odors was significant for all three groups. These results suggest that all subjects, regardless of presence or side of hemispheric lesions, are able to voluntarily express negative or unpleasant subjective states (or experiences) in a graded manner, with more unpleasant odor experiences being expressed more intensely. This implies coherence between facial behavior and subjective experiential systems, regardless of the presence of neurological lesions.

The fact that no relationships emerged between expression and experience to pleasant odors may be due to the limited ability of the pleasant odors to induce facial responses. However, a number of alternative explanations may also account for this lack of a relationship. First, subjects may not have necessarily found pleasant odors to be that pleasant, in contrast to unpleasant odors, which were clearly found to be unpleasant. When the mean percentage of participants who accurately classified the hedonic quality of the six odors used in the study was examined (averaging across nostril presentation and group), 78.2% categorized orange as pleasant, 68.9% categorized muguet as pleasant, and

68.5% categorized jasmine as pleasant; in contrast, 74.7% categorized butyric acid as unpleasant, 95.6% categorized thiophene as unpleasant and 73.9% categorized isovaleric acid as unpleasant.

A second, somewhat related explanation for the lack of findings for pleasant odors may be due to a inherent difficulty in measuring one's pleasant and unpleasant odor experience. The range of experiencing an unpleasant odor as unpleasant may be wider and more extreme than the range of experiencing a pleasant odor as pleasant, even if participants give identical values on a Likert rating scale for both pleasant and unpleasant odors. If the range in experiencing pleasant odors is more restricted, this may account for the lack of a significant relationship between experience and expression.

A third explanation for the lack of a relationship between experience and expression when using pleasant odors, is perhaps, that the intensity of hedonic experience induced by pleasant odors was not strong enough to evoke congruence between the experiential and expressive systems (see e.g., Tassinary& Cacioppo, 1992). Since hedonic intensity was greater for unpleasant in comparison to pleasant odors, perhaps this is why a relationship emerged for the unpleasant odors. For example, in research reviewed by Tassinary and Cacioppo (1992), higher levels of emotional intensity produced greater emotion-specific differentiation achieved across the facial muscles via specific recruitment of facial muscle units.

A final explanation for the lack of an association between experience and expression for pleasant odors is that expressions of pleasantness (i.e., smiles) may not necessarily be a true indicator of subjects' experiential states. In social situations, a smile

may be used to mask negative feelings or be used just to appear interested when engaged in a rather dull dialogue. In fact, many researchers have argued that only one type of a smile (the Duchenne smile) truly reflects positive experiential states (e.g., Ekman, 1984; Ekman, Davidson & Friesen, 1990). In the current study, differentiating "felt" from "unfelt" smiles was not done. If the Duchenne marker (e.g., activation of specific orbicularis oculi muscles) in smiles had been examined, it is possible that a significant relationship between experience and expression might have emerged for the pleasant odors.

Overall, the data indicated that no clear dissociations between perception/experience and expression were seen in the participants with hemispheric lesions. This is in contrast to studies by others suggesting that such dissociations do occur. Cimino et al. (1991) found that emotional monologues to autobiographical events produced by subjects with right hemisphere damage were rated as being less emotional than healthy controls, but the patients' ratings regarding the emotional significance of these events (an intensity scale) did not differ between the two groups. Likewise, appreciation of affective slides was similar in healthy individuals and individuals with left- and right-hemisphere damage, but those with right hemisphere damage had abnormal autonomic responses (Meadows & Kaplan, 1994).

The significant relationships which were found between experiential and expressive components in the current study may be related either to the statistical methods used in examining this relationship or to the stimuli and methods used to elicit such responses. In any event, the findings suggest that experience and expression to odors, especially for

prompted expressions, are interrelated processes, regardless of presence and side of hemispheric damage.

Summary and Conclusions

The purpose of this study was to determine if differences in hedonic experience emerged in individuals with right and left hemispheric lesions, and to explore the validity of two different neuropsychological theories of emotion – the right hemisphere hypothesis and the valence hypothesis. Hedonic experience was examined under a number of different conditions, including facial responses to pleasant and unpleasant odors, as well as subjective ratings of odors. For facial responses to odors, results indicated that there were no compelling group differences which supported either hypothesis, regardless of whether the facial displays were spontaneously evoked to odors or whether participants were prompted to express their odor experience. These findings were compared to posed hedonic expressions and to posed facial expressions of six discrete emotions, both elicited by verbal command. Although no group differences emerged for posed hedonic expressions, results for the posed emotional expression task supported the right hemisphere hypothesis. Differences in elicitation methods may be related to differences in a cortical versus subcortical route in processing the hedonic and affective information and/or to the level of complexity of the tasks. Since almost all participants in the right- and left-hemisphere groups had cortical lesions, the results implicate the right neocortical region in processing higher level, or symbolic, aspects of emotional information. In order to successfully perform the posed emotional expression task, multiple, intact cortical

modules in the right hemisphere may be required; these brain substrates may not be as necessary in order to achieve adequate performance when expressions are produced to odors or when posing pleasant and unpleasant expressions. In any event, the findings regarding facial displays to odors and posed hedonic expressions do not support the valence hypothesis, in that expression does not appear to be differentially modulated by the cerebral hemispheres as a function of valence.

Hedonic experience was also examined by subjective ratings of odors. Performances between LHD, RHD and NC subjects were seen as a function of perceived intensity, with RHDs reporting less intense ratings of odors than NCs when odors were presented to the right nostril. These findings also lend support for the right hemisphere hypothesis. They differ from findings by other investigators who report no differences in ratings of emotional experience as a result of neurological damage, but perhaps ratings of odor experience is a more sensitive measure than the methods used in previous studies.

Hedonic behaviors were also examined in the three groups of subjects, including choice behaviors and avoidance responses. For choice behaviors, there was a tendency for LHDs to choose fewer pleasant odors. This finding tends to support the valence hypothesis, but this effect did not reach statistical significance. Avoidance responses exhibited in the three groups of subjects were examined to determine if the right hemisphere is dominant in withdrawal action tendencies. The findings indicated that LHDs were more likely to exhibit these responses than RHDs and NCs. Although this finding was not expected, it is in keeping with reports of exaggerated affective reactions (i.e., catastrophic reactions) in individuals with LHD. These results are not necessarily

incongruent with the speculation of right hemisphere involvement in avoidance responses, as the left hemisphere may act to control emotional responses, inhibiting right hemisphere tendencies; lesions in the left hemisphere result in disinhibition and the release of right hemsphere functions.

In summary, reductions in performance and disinhibition of particular behaviors in hedonic and emotional processing were observed in the current study. Overall, these findings implicate the role of the right hemisphere in emotional processing, rather than providing support for the valence hypothesis. This study also suggest that symbolic, higher-level components of emotion rely more heavily on right neocortical regions than more fundamental aspects of emotion, such as pleasant and unpleasant experience and expression. It appears that the dimension upon which emotions are lateralized is not at the level of hedonics (or valence). Thus, future investigations using this dimensional approach (i.e., valence) in neuropsychological studies of emotion may not be that fruitful in enhancing our understanding of brain-behavior relations. Therefore, a different avenue of investigation is warranted. Proposals for future neuropsychological theories of emotion need to incorporate the cognitive aspects of emotion (e.g., appraisal) to better understand hemispheric asymmetries in emotional processing.

APPENDIX 1

Piloting Procedures Used in Choosing Odorants

Overview

For this study, odorants selected were based on four requirements: (1) that odorants would selectively stimulate the olfactory and not the trigeminal nerve; (2) that 80% of a pilot sample of subjects would find the odors either pleasant or unpleasant; (3) that odorants were judged to be in the middle range of hedonic intensity to avoid any potential ceiling or floor effects; and (4) that pleasant and unpleasant odorants were matched in terms of hedonic intensity.

The first requirement was met by piloting a number of odorants ranging in intensity on individuals with documented anosmia. The second and third requirements were met by asking older individuals (who were approximately the same age as those seen with unilateral lesions) to rate several odorants ranging in intensity (see Madigan et al., 1994). As procedures for the first requirement have not been published, these procedures will be reviewed. A brief overview for the last two requirements is provided.

Testing of Anosmic Subjects

Subjects: Four individuals (one woman, 3 men) with clinically documented anosmia were seen for this pilot study. Three individuals had congenital anosmia, with one having anosmia secondary to head trauma. The subjects ranged in age from 24-65 (M = 47.8, s.d. = 18.7), and had an average of 15.0 years education (S.D. = 2.6 years). Three subjects were right-handed and one was left-handed.

Odorants: Twelve odors were selected for perceived level of pleasantness/unpleasantness based on previous work, with half being pleasant, half being unpleasant (Ehrlichman, personal communication). The six pleasant odors were: orange, coconut, jasmine, almond, muguet, and pina colada. The six unpleasant odorants were: thiophene, pyridine, isovaleric acid, butyric acid, thiophenol and skatol. Odorants were obtained from International Flavors and Fragrances, Inc., or from the Queens College Chemistry Department (thiophenol). These odorants were then diluted by volume by logarithmic increments, with concentrations beginning at full strength with dilutions to 0.11%, so that a total of 9 concentrations were prepared for each odorant. All odorants except coconut and almond were prepared in diethyl pthalate, an odorless solution; coconut and almond were prepared in water.

Procedure: Separate fragrance sniff strips were dipped into each solution several hours prior to testing. Odorants were stored in glass test tubes, as described in the Methods section for the experiment proper.

To determine threshold detection via the trigeminal nerve, a forced choice procedure was used, where subjects were presented with two fragrance strips, one containing the odor and the other consisting of a blank. Subjects were instructed to "choose the odor which smelled stronger". Subjects were asked to take two sniffs of each odor.

Odorants were presented to subjects in descending series, beginning with the highest concentration. If the subject correctly identified the odorant, a duplicate set was given again (consisting of the same concentration of the odorant and a blank strip) until

five consecutive correct choices were made. All five trials must be correct for the odorant to be considered detectable by the subject. If all five trials were correct, the next concentration of the same odorant in the descending series was administered. If the odorant was not correctly identified for any of the five trials, a different odorant was given. A total of four thresholds were obtained for each odorant. Specific odorants were randomized for each subject, but order of delivery alternated between presentation of a pleasant and unpleasant odor.

Results: Odorant concentrations were considered to be below threshold for detection by the trigeminal nerve if none of the anosmic subjects could detect the odorant at that concentration over all four threshold trials.

A listing of odorants (with concentrations) which were not detected by the subjects is provided. For pleasant odors, none of the subjects could detect: orange (33%), coconut (100%), jasmine (33%), almond (33%), muguet (100%), and pina colada (33%). For the unpleasant odors, no subject could correctly detect: thiophene (33%), pyridine (11%), isovaleric acid (33%), butyric acid (33%), thiophenol (33%), and skatol (100%).

Piloting procedures with healthy older adults

Brief overview. More detailed information regarding these procedures are provided in Madigan et al. (1994). Subjects consisted of twenty subjects (10 men, 10 women) who were a mean age of 65.8 years (SD = 6.7). Six pleasant and six unpleasant odoras were prepared to vary the intensity of pleasantness or unpleasantness so that a total of 36 odors were used. Concentrations of each odorant were as follows: orange, jasmine,

pina colada, muguet, almond, butyric acid, and skatol (each at 10%, 20%, 30%); coconut (10%, 20%, 100%); pyridine (0.1%, 0.5%, 1.0%); thiophenol (.001%, .005%, .01%); isovaleric acid (5%, 15%, 30%); and thiophene (1%, 5%, 10%). All concentrations of odorants were below concentrations detected by the trigeminal nerve, based on the initial piloting with anosmic subjects.

Each odorant was presented twice during the testing session. Odors were presented in both in same-valence blocks, i.e., all pleasant ones first, all unpleasant ones second, or vice versa, and in alternation. Subjects were asked to indicate the hedonic quality of the odor (pleasant, unpleasant, neither). If the odorant was perceived as pleasant or unpleasant, subjects were asked to indicate the pleasantness or unpleasantness by a plexiglass scale, with a movable pointer. From the subject's view, five verbal anchors were provided to the subject ("slightly", "somewhat", "moderately", "very", "extremely"). On the back of the scale, the scale ranged from 1 to 100 in increments of 5. Numerical values corresponded to the verbal anchors on the front as follows: "slightly" was equal to 1, "somewhat" was equal to 25, "moderately" was equal to 50, "very" was equal to 75, and "extremely" was equal to "100". The numerical values were read from the scale by the experimenter for each trial. Percent agreement for hedonic quality and average hedonic intensity ratings for pleasant and unpleasant odors were calculated for each odor at each concentration. If the subject perceived an odor as having a different hedonic quality than that which was intended, the rating for that odorant was not included when calculating the average hedonic intensity rating. Across the 72 odorant trials, such mismatches accounted for 11.3% of the trials.

Results: Table 56 below depicts the average percent category agreement for the 36 odorants, as well as the average hedonic intensity ratings. As can be seen, the perceived hedonic quality of most odorants agreed with a priori classification (e.g., 80% criterion).

On the basis of these results and the four requirements for odorant selection, three pleasant and three unpleasant odors were chosen for use in the experiment proper. The three pleasant odors were muguet (30%), jasmine (10%) and orange (30%). The unpleasant odors were isovaleric acid (5%), thiophene (1%) and butyric acid (30%).

Table 56. Results of piloting procedures for odorant selection

Odorant	Concentration	Hedonic Quality (% agreement)*	Average Hedonic Intensity	
			M	SD
Pleasant odors				
Orange	10%	87.5	43.2	25.6
	20%	90	44.6	26.5
	30%	95	50.7	28.3
Jasmine	10%	92.5	53.7	19.4
	20%	85	47.6	23.0
	30%	90	49.0	22.0
Pina colada	10%	87.5	45.1	18.4
	20%	87.5	40.2	28.8
	30%	92.5	48.9	23.5
Muguet	10%	92.5	45.8	23.7
	20%	90	48.2	26.6
	30%	92.5	50.3	30.1
Almond	10%	80	44.9	28.1
	20%	90	41.7	22.7
	30%	70	40.9	19.7
Coconut	10%	85	49.7	26.1
	20%	87.5	43.9	22.1
	30%	85	45.3	20.6
Unpleasant odors				
Pyridine	0.1%	57.5	36.8	25.9
	0.5%	90	43.4	22.7
	1.0%	92.5	45.5	25.6
Thiophenol	0.001%	97.5	52.1	26.8
	0.005%	92.5	63.1	26.6
	0.01%	95	60.4	26.5
Butyric acid	10%	85	46.8	25.8
	20%	92.5	57.6	20.0
	30%	90	56.1	25.0
Isovaleric acid	5%	92.5	53.9	29.0
	15%	90	56.6	20.3
	30%	95	55.8	28.8
Thiophene	1%	95	52.8	26.6
	5%	92.5	61.3	26.4
	10%	92.5	63.8	23.9
Skatol	10%	67.5	32.7	18.6
	20%	70	37.2	22.9
	30%	80	30.8	24.2

*Percent accurate agreement for hedonic quality.

APPENDIX 2

Instructions to Subjects for Conditions Using Odors

1. Introduction to this part of the study

"For this session, we're interested in learning how people react to different odors. Some of the odors may be unpleasant, but not harmful to you, whereas others will be pleasant. The odors will be presented to you on thin strips of paper. Each nostril will be tested separately so that you can optimally experience the odor. A cotton ball will be used to plug up one nostril. An audiovisual recording will be made to have a record of the experiment and to cut down the time needed to take notes during the experiment. When we begin, I'm going to ask you to try and not talk while I am presenting the odors to you. Do you have any questions about anything so far?"

2. Condition 1 (Spontaneous Facial Expression)

"Now I am going to plug up one nostril so that you can maximally experience the odor. I'm doing this so that you'll become familiar with the odors presented to you in this manner. Remember to take two sharp sniffs each time I give you an odor to smell. Also, try not to talk while I am presenting the odors to you. I'd like you to sit up straight and look straight ahead. Before we begin, do you have any questions?"

3. Condition 2 (Prompted Facial Expression)

"This time when I present the odors to you, I'd like you to try to experience the odor as fully as you can, then to show on your face how the odor makes you feel."

A. Warm-up exercises

"Since facial movement is an important part of any expression, before we begin I would like you to practice moving different parts of your face. Please exaggerate these movements. Pretend that you are an actor or actress rehearsing a role. Let's try these movements together."

a. Mouth: open and close

b. Eyes: open & close

c. Cheek: up & down

d. Nose: wrinkle it up

e. Chin: up and down.

B. Procedure

"Now, when I present the odors to you, I'd like you to try to experience the odor as fully as you can, then to show on your face how the odor makes you feel when I say 'Ready, go'. We will do this several times. Again, I am going to plug up one nostril while you are smelling the odor. Take two sharp sniffs of the odor. Try not to talk while I am presenting the odors to you, and while you are expressing how the odor makes you feel. Remember, your task is to try to experience the odor as fully as you can, then to show on your face how the odor makes you feel when I say 'Ready, go'. I'd like you to hold the pose for a few seconds then relax your facial muscles. Do you have any questions?"

4. Condition 3 (Experiential Ratings)

"This time, I am going to ask you how you experience each odor. When I present each odor to you, I want you to tell me if you experience the smell as pleasant, unpleasant,

or neither. You can either tell me if you would categorize the odor as pleasant, unpleasant or neither pleasant nor unpleasant, or indicate your response by pointing to one of these faces on this card (present response card)."

(Experimenter points to the pleasant face)

"By pointing to this face, you would indicate that the odor is pleasant". Similar instructions are used for the unpleasant and neutral faces.

"If you experience the odor as either pleasant or unpleasant, I am going to ask you how pleasant or unpleasant you find it by using this scale. The scale ranges are from +10 to - 10, with +10 indicating 'extremely pleasant', + 10 indicating 'extremely unpleasant', and then directly in the middle is 0 indicating 'neither pleasant/unpleasant'. Also notice where the labels 'moderately pleasant' and 'moderately unpleasant' are on the scale."

"So, if you smelled an odor that you thought was very pleasant, you might rate it as being a +7 or a +8, if it was only somewhat pleasant, you might rate it as a +2 or a +3, and if it was only moderately pleasant, your rating might be a +4 or +5. If you thought the odor was slightly unpleasant,you might give it a rating of a -2 or a -3, if it was extremely unpleasant, a rating of a -9 or -10, and if it was moderately unpleasant, a -5 or -6. It's important that you use the full range of the scale, and <u>not</u> just to point to the numbers next to the labels indicated."

"I want you to give only one rating per odor. I'd like you to both call off and to point to the number which indicates your rating. Remember to take two sniffs of each odor when I present them to you. Do you have any questions?"

5. Condition 4 (Behavioral Choice Measures)

"I am going to present three pairs of different odorants to you. For each of these pairs, I want you to choose 1 that you would like to smell for a period of 30 seconds later in the study. I will present these pairs of odors to each nostril separately; for each nostril, I want you to choose one of each pair of odors that you would like to smell later. You have as long as you'd like to make your choices when I am presenting the odors to you, but I am going to ask that you choose one of each pair that you would most like to smell later on."

6. Condition 5 (Spontaneous Facial Expression to Unpleasant Odors)

"In this part of the experiment, there may be some very unpleasant odors. None of these odors are harmful to you. Since some people find some of the odors quite unpleasant, you have the option of not participating in this part of the experiment."

"If you do participate, I will present the odors to each nostril separately. After I finish presenting all of the odors to you, I will ask you some questions about them. While I am presenting the odors, it's important that you do not talk. Would you like to participate in this part of the experiment?"

(IF YES), "Do you have any questions regarding this part of the experiment?"
Present the odors to the subject.

"I want you to tell me if the method of presentation (R vs. L nostril) altered your experience of the odors. Did you experience them as less intense when given to your left nostril, or right nostril?"

(IF NO) "Okay, that's fine, I'd just like to know why you would rather not participate. It's important for us to know how you are feeling right now and your reasons for not taking

part in this part of the study."

7. Presentation of pleasant odors selected earlier

"Remember the odors you chose earlier? I am going to present each one to you for several seconds. If you'd like to sniff them longer, let me know".

APPENDIX 3

Instructions to Raters for Initial Training Session - Spontaneous Expressions to Odors (Conditions 1 and 5)

"You are going to see videotaped segments of people smelling some odors. The odors given to the subjects vary in intensity and pleasantness. The odors ranged from mildly to extremely pleasant and from mildly to extremely unpleasant. Subjects are also given odors which they may find neither pleasant nor unpleasant."

"For this study, subjects were asked to sniff some odors, which were presented on small strips of paper held underneath the subject's nose. For each trial, you will note that one of the subject's nostrils is blocked with a cotton plug. This was to control for a nasal patency effect. Nasal patency refers to the amount of air flowing through each nostril. Whether you realize it or not, the air flow through each nostril is cyclical, where for part of the day, one nostril is more open than the other. We wanted to control for this effect by blocking off one nostril. In this way, we can compare the amount of air flow through the nostril to our measures of interest."

"Your job today and over the subsequent sessions is to make some ratings for this study, based on the subject's response to the odor. You might be wondering what I mean by a response to an odor. In this study, we're interested in two types of responses: facial expressions and avoidant responses. From your examination of these responses, you will be asked to make 3 ratings."

"For each trial, you will determine the following:

1. Hedonic quality (i.e., whether the subject found that the odor was pleasant, unpleasant or neither);
2. Hedonic intensity (i.e., how pleasant or unpleasant the subject found the odor);
3. Presence of an avoidance response (i.e., whether or not the subject made a response to move away from the odor)."

"**HEDONIC QUALITY** refers to whether or not the subject found the odor pleasant, unpleasant, or neither pleasant or unpleasant. There are two types of responses to help you determine hedonic quality. One type of a response is a facial expression to indicate that he/she finds the odor pleasant or unpleasant. Another type of a response is an avoidant response to an odor which he/she finds unpleasant. I'll describe this second type of a response to you shortly."

"In terms of facial expression, an expression to an odor which is pleasant might be indicated by the following features:

- The corners of the lips are drawn back and up
- The cheeks may be raised
- A wrinkle may extend from the outer edge of the nose to the corners of the mouth."

"A facial expression to an odor which is unpleasant might be indicated by the following features:

- The nose may be wrinkled
- The upper lip is raised while the lower lip is either raised or lowered

- The eyebrows may be lowered."

"Another type of a response to indicate the odor is unpleasant that the subject may make is a response to avoid the odor. Sometimes, when someone smells an odor which is unpleasant, he/she might move, turn, or jerk his/her head away from the odor, or he/she might blink the eyes. This response will often look like an involuntary reflex. The eye blinking and head movements will also appear to be exaggerated."

"An expression to an odor which is neither pleasant or unpleasant might be determined in two different ways: 1) you would observe no change in the muscular activity on the face; or 2) there is a change in the muscular activity on the face, but the resulting facial expression looks neither pleasant nor unpleasant."

"For each trial, you will try to determine if the person is smelling an odor which is pleasant, unpleasant, or neither pleasant nor unpleasant, and then circle the appropriate choice on the answer sheet. Just to remind you, that if you thought the person is smelling a pleasant odor, this should be based on the person's facial expression. On the other hand, your judgment of an unpleasant odor should be based on the person's facial expression and/or an avoidance response. "

"Let's review some examples of subjects smelling some odors and responses which indicate that the subject is smelling an odor which is pleasant, unpleasant or neither pleasant nor unpleasant."

VIDEOTAPE EXAMPLES 1-9 WERE SHOWN

Example 1: "This is an example of a subject smelling a pleasant odor. You would circle 'pleasant' to indicate hedonic quality".

Example 2: "This is another example of a response to a pleasant odor. Here, you would circle 'pleasant' to indicate hedonic quality".

Example 3: "Here's a third example of a subject smelling a pleasant odor. Again, you would circle 'pleasant' to indicate hedonic quality".

Example 4: "This is an example of a subject smelling an unpleasant odor. You would circle 'unpleasant' to indicate hedonic quality".

Example 5: "Here's another example of a response to an unpleasant odor. You would circle 'unpleasant' to indicate hedonic quality".

Example 6: "Here's a third example of a response to an unpleasant odor. You would again circle 'unpleasant' to indicate hedonic quality".

Example 7: "Here's a response indicating that the subject finds the odor neither pleasant or unpleasant. You would circle 'neither' when rating hedonic quality".

Example 8: "Here's another example of a neither response. Again, you would circle 'neither' when rating hedonic quality".

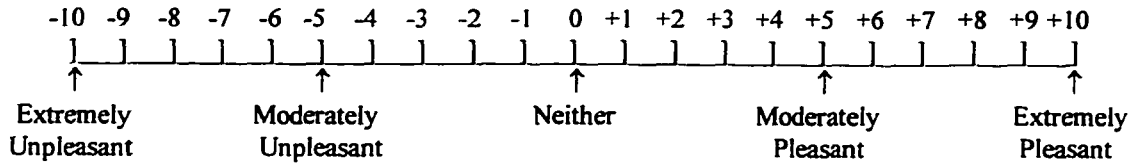
Example 9: "Here's a third example of a neither response. You would circle 'neither' to indicate hedonic quality".

"Does anyone have any questions?"

"The second rating you will determine is **HEDONIC INTENSITY**. Hedonic intensity refers to how pleasant or unpleasant the person finds the odor. Ratings of hedonic intensity are based solely on the person's facial expression. In this study, hedonic intensity is inferred by the degree of musculature involvement in the facial expression. Clues as to the intensity of a facial

expression are obtained from observing several features, such as the tightness of the skin around the eyes and mouth, the depth of the nasolabial fold (the wrinkle on the face extending from the outer edge of the nose to the outer edge beyond the mouth), the amount of wrinkles seen at the bridge of the nose, and the amount of drawing up or down of the cheeks, eyebrows, mouth and chin. In a moment, I'll describe to you how you might interpret eye blinking."

"To determine hedonic intensity, you should use the following scale as a guideline."



"Note that the scale ranges from +10 to -10, with +10 indicating 'extremely pleasant' and -10 indicating 'extremely unpleasant'. Directly in the middle of the scale is 0 indicating 'neither pleasant/unpleasant'. Also notice that a +5 would indicate 'moderately pleasant' and a -5 would indicate 'moderately unpleasant'."

"So, if you thought the person was smelling an odor that was very pleasant, you might give that trial a rating of a +7 or +8; if you thought that the subject was smelling an odor which was only somewhat pleasant, your rating would be a +2 or +3; and if the response indicated the odor was only moderately pleasant, your rating would be a +4 or +5. If you thought the person's response indicated that the odor was only slightly unpleasant, your rating would be a -1 or -2; if it was extremely unpleasant, your rating would be a -9 or -10; and if it was moderately unpleasant, your rating would be a -5 or -6. It's important for you to use the full range of the scale to describe the intensity of the facial expression, and not to just circle the numbers next to the labels indicated. Are there any questions?"

"You should understand that if you feel that the facial expression indicates the odor is pleasant, then hedonic intensity must be rated on the scale from +1 to +10. You are being asked to determine if the odor is pleasant based on the person's facial expression. Therefore, according to the guidelines of this study, there must be some contraction of the facial muscles. Thus, hedonic intensity for an expression to a pleasant odor must range in intensity from +1 to +10."

"You should also understand that for an unpleasant odor, your ratings are based on two types of responses: facial expressions and/or avoidant responses. In this case, hedonic intensity would be rated on the scale from 0 to -10. As we discussed in the initial session, a subject may make an avoidant response, indicating the odor is unpleasant, but there may be no change in his/her facial expression. If an avoidance response occurs, and there is no change in the facial expression, then hedonic intensity is rated as 0. But, if you determine that the response indicates that the odor is unpleasant, and no avoidance response occurs, then according to the guidelines of this study, your judgment must be based solely on the facial expression, meaning that there is a change in the contraction of the facial muscles indicating the odor is unpleasant. In this case, hedonic intensity must range in intensity from -1 to -10."

"Let's review some photographs of facial expressions which range in intensity. These examples are meant to demonstrate how expressions differ in intensity, and how the expressions would be rated on the scale."

SAMPLE PHOTOGRAPHS 1 - 11 WERE SHOWN: (4 happy and 4 disgust expressions varying in intensity and 3 happy expressions)

Photo sample 1: "This expression is about a +2 or +3 on the scale".

Photo sample 2: "This expression is about +5 or +6 on the scale".

Photo sample 3: "This expression is about a +7 on the scale".

Photo sample 4: "This expression is about a +8 or +9 on the scale".

Photo sample 5: "This expression is about a -2 or -3 on the scale".

Photo sample 6: "This expression is about a -5 or -6 on the scale".

Photo sample 7: "This expression is about a -7 on the scale".

Photo sample 8: "This expression is about a -8 or -9 on the scale".

"Now I'll show you some photographs of facial expressions demonstrating how one person's expression can vary in intensity."

Photo sample 9: "This expression is about a +1 or +2 on the scale".

Photo sample 10: "This expression is about a +5 or +6 on the scale".

Photo sample 11: "This expression is about a +8 or +9 on the scale".

"Now we'll review some videotaped clips to demonstrate how the expressions range in hedonic intensity. Also, please refer to the rating sheets, since you would circle the appropriate number on the 21-point scale."

VIDEOTAPED EXAMPLES 1 - 9 WERE SHOWN AGAIN

Example 1: "This response would receive a rating of a +2 or +3".

Example 2: "This would receive a rating of a +3 or +4".

Example 3: "This would receive a rating of a +2 or +3".

Example 4: "This expression would receive a rating of a -3".

Example 5: "This would receive a rating of a -2 or -3".

Example 6: "This would receive a rating of a -3".

Example 7: "This response indicates that the subject finds the odor neither pleasant or unpleasant, so you would not rate hedonic intensity".

Example 8: "Here's another example of a neither response, and again hedonic intensity is not rated".

Example 9: "Here's a third example of a neither response; there's no need to rate hedonic intensity".

"The third rating you will determine is the PRESENCE OF AN AVOIDANCE RESPONSE. Sometimes, when someone smells an odor which is unpleasant, he/she might move, turn or jerk his/her head away from the odor, or the subject might blink his/her eyes. This response will often look like an involuntary reflex. The eye blinking and head movements will also appear to be exaggerated."

"Let's review some examples of an avoidance response. Again, an avoidance response will almost seem involuntary. It's indicated by a subject moving, turning or jerking the head away from the odor, or by an exaggerated blinking of the eyes."

VIDEOTAPED EXAMPLES 10 - 12 WERE SHOWN

Example 10: "Here's an example of an avoidant response to an unpleasant odor".

Example 11: "Here's another example".

Example 12: "Here's a third example. In this case the subject moved his head away from the odor as well as blinked his eyes".

"Remember that an avoidance response here is indicated by a subject moving, turning or jerking his/her head away from the odor, or by an exaggerated blinking of the eyes."

Eye blinking. "Understand that eye blinking can occur as part of an avoidance

response, as part of a facial expression, or as just a part of normal eye blinking. In cases where the blinking appears to be exaggerated or like an involuntary reflex, this would be indicative of an avoidance response. In another instance, blinking might be more a part of a facial expression indicating pleasantness or unpleasantness and not an avoidance response, and thus, would be considered only when making your ratings of hedonic quality and intensity about the facial expression. I know this sounds rather ambiguous, but I'll be showing you another example later on to demonstrate when eye blinking occurs as part of a facial expression. It is important for all of you to remember that there are no right or wrong answers when making your ratings. Your ratings are merely based on your perception of a person's response, as you try to follow the guidelines I've given to you during this session."

"You should also understand that your rating of whether or not an avoidance response occurs is independent of your rating of hedonic intensity. For instance, the person might turn or jerk his/her head away from the odor, but there may be no change in facial expression, meaning that you might note no change in the contraction of the muscles on the face itself. In this case, you would circle 'unpleasant' indicating that the subject finds the odor unpleasant, but hedonic intensity would be rated as '0'. You would also circle 'yes', indicating an avoidance response occurred."

"Now we'll review those three examples again to demonstrate how ratings of the avoidance response are independent of ratings of hedonic intensity. You should also refer to your rating sheets to understand how to rate the three ratings".

VIDEOTAPED EXAMPLES 10-12 WERE SHOWN AGAIN

Example 10: "Here the person's response indicates that the odor is unpleasant. So, for

hedonic quality, you would circle 'unpleasant'. Note that there is no change in the contraction of the facial muscles, so hedonic intensity would be rated as '0'. The person does make an avoidance response, so for avoidance response, you would circle 'yes'".

Example 11: "In this example, the subject's response indicates the odor is unpleasant. For hedonic quality, you would circle 'unpleasant'. An avoidance response co-occurs with a change in facial expression. The facial expression indicates that the odor is somewhat unpleasant, and so hedonic intensity would receive a rating of about a -3 on the scale. An avoidance response has also occurred, so for avoidance response, you would circle 'yes'".

Example 12: "Here's another example of a response indicating the odor is unpleasant. Hedonic quality would be rated as 'unpleasant'. Hedonic intensity would be rated as '0', because there is no change in the facial expression. An avoidance response occurs, so for Avoidance response, you would circle 'yes'. Note that the subject not only turns his head away from the odor, but also blinks his eyes, so eye blinking is part of the avoidance response. Understand that the eye blinking and head turning are not rated for intensity, as they are a part of the avoidance response, and not part of a facial expression."

"Again, there are only two types of movements you should take into account when making your ratings: facial expressions and avoidant responses. Other types of movements or responses should be ignored, such as talking, swallowing, coughing or nodding. You should not consider such movements when making your judgments as to whether the subject finds the odor pleasant, unpleasant or neither. Such movements are often misleading. For example, some subjects may nod their heads when the odor is administered, to indicate that they have smelled it. Thus, nodding should not be taken to indicate anything about the pleasantness of

the odor. Again, you should ignore any extraneous movements when making the three ratings, except for movements indicative of an avoidance response."

"Now we'll review all 12 examples again, and discuss how each trial would be rated for each of the 3 measures of interest. If you do not understand why the trial would receive a rating, please ask me, and we'll review the trial together. You should understand that from now on, you will be required to determine the three ratings at one time, rather than reviewing each trial three times to determine each rating".

VIDEOTAPED EXAMPLES 1-12 WERE SHOWN

Example 1: Pleasant, +2 or +3, no avoidance

Example 2: Pleasant, +3, no avoidance

Example 3: Pleasant, +2 or +3, no avoidance

Example 4: Unpleasant, -3 or -4, no avoidance

Example 5: Unpleasant, -2 or -3, no avoidance

Example 6: Unpleasant, -2 or -3, no avoidance

Example 7: Neither, no rating, no avoidance

Example 8: Neither, no rating, no avoidance

Example 9: Neither, no rating, no avoidance

Example 10: Unpleasant, 0, yes avoidance

Example 11: Unpleasant, -3, yes avoidance

Example 12: Unpleasant, 0, no avoidance

THE EXAMPLES WERE REVIEWED BY THE RATERS AS MANY TIMES AS NEEDED TO ENSURE THAT THE RATERS UNDERSTOOD THE RATINGS FOR

EACH TRIAL. WHEN NEEDED, EXAMPLES WERE VIEWED AT SLOWER SPEEDS TO ENSURE THAT THE JUDGES SAW THE RESPONSES AND UNDERSTOOD HOW TO RATE EACH TRIAL.

Training Session, Part II

"Now I'm going to ask you to make some practice ratings of subjects' responses to odors. This is to familiarize you with the procedures used during these sessions, as well as to ensure that you understand what I'm asking you to do. Please refer to the sheets onto which you will record your ratings. Ratings for each trial will be recorded on separate pieces of paper."

"For each trial, I will first ask you to determine if a subject finds an odor pleasant, unpleasant or neither pleasant nor unpleasant. You'll indicate this by circling your choice (i.e., P, U, N). If you think the person is smelling an odor which is either pleasant or unpleasant, I'd like you to rate hedonic intensity on the 21-point scale by circling the appropriate number. The third rating you will make is whether the subject makes an avoidance response during the trial, by circling 'yes' or 'no'."

"Each trial will be presented to you for several seconds. I want you to wait until I say, 'Go ahead' (i.e., the end of the trial), to make your ratings. You will then have ten seconds to record your ratings. For this part of the study, I will strongly encourage you to make a rating for each of these practice trials."

"After you have completed your ratings for each trial, I will ask each of you to tell me

what your ratings are for that trial. In this way, you can compare ratings and learn strategies which may assist you in making your ratings. After each trial, I'd like you to discuss the strategies you used to make your decisions. After this discussion is completed, I'll ask you to rate that trial again. I'd like you to take into account strategies highlighted by others which may help you in making your ratings when viewing the trial a second time. But, your second rating of the trial should still be based upon what you think."

Training example 1: Unpleasant, 0, Yes

Training example 2: Neither, no rating, No

Training example 3: Unpleasant, -3 OR -4, No

Training example 4: Unpleasant, -4, No

Training example 5: Pleasant, +2 OR +3, No

Training example 6: Neither, no rating, No

Training example 7: Unpleasant, 0, Yes

Training example 8*: Unpleasant, -2 OR -3, No

*eye blink is part of a facial expression & not an avoidant response

Training example 9: Pleasant, +5 OR +6, No

Training example 10: Pleasant, +3 OR +4, No

Training example 11: Unpleasant, 0, Yes

Training example 12: Unpleasant, -6 OR -7, Yes

Training example 13: Neither, no rating, No

Training example 14: Unpleasant, -6 OR -7, No

Training example 15: Unpleasant, -8, No

Training example 16: Pleasant, +2 OR +3, No

Training example 17: Unpleasant, -5 OR -6, No

Training example 18: Neither, no rating, No

ALL 18 TRAINING EXAMPLES WERE SHOWN, USING THE PROCEDURE DESCRIBED ABOVE. RATERS' RESPONSES WERE RECORDED AFTER EACH TRIAL. COMMENTS AND STRATEGIES USED FOR EACH TRIAL WERE ALSO RECORDED.

ESTABLISHING INITIAL INTER-RATER RELIABILITY

"Now I'll ask you to rate some other trials. For each trial, you will be asked to make the three ratings. Please wait until the end of the trial to make your ratings. You will then have ten seconds to complete your ratings. From now on, you cannot review any trial. You are strongly encouraged to make all 3 ratings for each trial. However, if you feel that you are unable to make one of the three ratings, please circle "cannot judge" for that particular rating. Please circle "cannot judge" for any rating you cannot make on any given trial. This might be the case if you feel that your rating would be completely random or if you feel you missed the response on the trial. For instance, you might feel you cannot rate hedonic intensity for a given trial, so you would circle "cannot judge". However, you should go ahead and complete your ratings for hedonic quality and presence of an avoidance response, if you feel you can make such ratings. After completing your ratings, turn over the page and wait for the next trial. I will tell you what trial number we are on to ensure that everyone is on the correct page when making the ratings. As these ratings are to be made independently, please do not discuss your ratings amongst yourselves. Does anyone have any questions?"

APPENDIX 4

Instructions to Raters for Initial Training Session -

Prompted Expressions to Odors (Condition 2)

"You are going to see some more videotaped segments of people smelling some odors. As before, the odors given vary in intensity and pleasantness. The odors ranged from mildly to extremely pleasant and from mildly to extremely unpleasant. Subjects are also given odors which they may find neither pleasant nor unpleasant."

"For this part of the study, the subjects were asked to deliberately show on their face how they found the odor, that is whether they found the odor to be pleasant, unpleasant or neither pleasant nor unpleasant. For this part of the study, you will be asked to make two ratings."

"For each trial, you will determine the following:

1. Hedonic quality (i.e., whether the subject found that the odor was pleasant, unpleasant or neither);
2. Hedonic intensity (i.e., how pleasant or unpleasant the subject found the odor).

"Although you are familiar with both of these measures, we'll quickly review what is meant by each of these ratings. **HEDONIC QUALITY** refers to whether or not the subject found the odor pleasant, unpleasant, or neither pleasant or unpleasant. A subject might make a certain type of facial expression to indicate that he/she found the odor pleasant or unpleasant."

"An expression to an odor which is pleasant might be indicated by the following features:

- The corners of the lips are drawn back and up
- The cheeks may be raised
- A wrinkle may extend from the outer edge of the nose to the outer edge beyond the lips."

"An expression to an odor which is unpleasant might be indicated by the following features:

- The nose may be wrinkled
- The upper lip is raised while the lower lip is either raised or lowered
- The eyebrows may be lowered."

"An expression to an odor which is neither pleasant nor unpleasant might be determined in two different ways: 1) you would observe no change in the muscular activity on the face; or 2) there is a change in the muscular activity on the face, but the expression looks neither pleasant nor unpleasant."

"For each trial, you will determine if the person is smelling an odor which is pleasant, unpleasant, or neither pleasant nor unpleasant, and then circle the appropriate choice on the answer sheet."

"Let's review some examples of subjects smelling some odors and responses which indicate that the subject is smelling an odor which is pleasant, unpleasant or neither pleasant nor unpleasant. All subjects were instructed to make the expression after they smelled the odor. Sometimes, subjects make an expression while they are smelling the odor, but you should only pay attention to the expression which occurs one or two seconds after the odor strip has been removed. You should understand that the procedures for this part of the study were as

follows: subjects were asked to take two sniffs of the odor, the odor strip was removed, and then the subject was asked to deliberately pose an expression. Therefore, your ratings should be based on the expression made after the subject smells the odor. "

VIDEOTAPE EXAMPLES 1-9 WERE SHOWN

Example 1: "This is an example of a subject who finds the odor as pleasant".

Example 2: "This is another example of a response to a pleasant odor".

Example 3: "Here's a third example of a subject smelling a pleasant odor".

Example 4: "This is an example of a subject who finds the odor as unpleasant".

Example 5: "Here's another example of a response to an unpleasant odor".

Example 6: "Here's a third example of a response to an unpleasant odor".

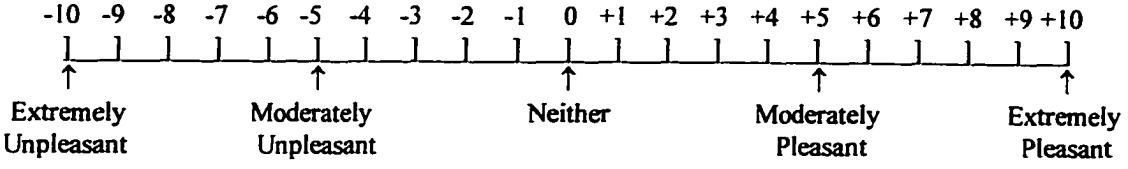
Example 7: "Here's a response indicating that the subject finds the odor neither pleasant or unpleasant".

Example 8: "Here's another example of a neither response".

Example 9: "Here's a third example of a neither response".

"The second rating you will determine is **HEDONIC INTENSITY.** As before, hedonic intensity refers to how pleasant or unpleasant the person found the odor based on his/her facial expression. In this study, hedonic intensity is inferred by the degree of musculature involvement in the expression. Clues as to the intensity of an expression are obtained from observing several features, such as the tightness of the skin around the eyes and mouth, the depth of the nasolabial fold (the wrinkle on the face extending from the outer edge of the nose to the outer edge beyond the mouth), the amount of wrinkles seen at the bridge of the nose, and the amount of drawing up or down of the cheeks, eyebrows, mouth and chin."

"To determine hedonic intensity, you will use the same scale used before as a guideline."



"I will show you some photographs of facial expressions which range in intensity. These examples are meant to demonstrate how expressions differ in intensity, and how the expressions would be rated on the scale."

SAMPLE PHOTOGRAPHS 1 - 11 WERE SHOWN: (4 happy/4 disgust expressions varying in intensity and 3 happy expressions)

Photo sample 1: "This expression is about a +2 or +3 on the scale".

Photo sample 2: "This expression is about a +5 or +6 on the scale".

Photo sample 3: "This expression is about a +7 on the scale".

Photo sample 4: "This expression is about a +8 or +9 on the scale".

Photo sample 5: "This expression is about a -2 or -3 on the scale".

Photo sample 6: "This expression is about a -5 or -6 on the scale".

Photo sample 7: "This expression is about a -7 on the scale".

Photo sample 8: "This expression is about a -8 or -9 on the scale".

"Now I'll show you some examples of how one person's expression can vary in intensity."

Photo sample 9: " This expression is about a +2 or +3 on the scale".

Photo sample 10: "This expression is about a +5 or +6 on the scale".

Photo sample 11: "This expression is about a +8 or +9 on the scale".

"Now we'll review some videotaped clips to demonstrate how the expressions range in hedonic intensity."

VIDEOTAPED EXAMPLES 1 - 9 WERE SHOWN AGAIN

Example 1: "This response would receive a rating of a +1 or +2".

Example 2: "This would receive a rating of a +5 or +6".

Example 3: "This would receive a rating of a +8 or +9".

Example 4: "This expression would receive a rating of a -2 or -3".

Example 5: "This would receive a rating of a -5 or -6".

Example 6: "This would receive a rating of a -7 or -8".

Example 7: "This response indicates that the subject finds the odor neither pleasant or unpleasant, so you would not rate hedonic intensity".

Example 8: "Here's another example of a neither response, and again hedonic intensity is not rated".

Example 9: "Here's a third example of a neither response; there's no need to rate hedonic intensity".

"For this part of the study, you will be asked to only make two ratings. You no longer need to note if an avoidance response occurs. Therefore, all extraneous movements should be ignored, including talking, nodding, and swallowing. You should only make your ratings based on the subject's facial expression."

"Now we'll review all 9 examples again, and discuss how each trial would be rated for

each of the 2 measures of interest. If you do not understand why the trial would receive a rating, please ask me, and we'll review the trial again".

VIDEOTAPED EXAMPLES 1-9 WERE SHOWN

Example 1: Pleasant, +1 or +2

Example 2: Pleasant, +5 or +6

Example 3: Pleasant, +8 or +9

Example 4: Unpleasant, -2 or -3

Example 5: Unpleasant, -5

Example 6: Unpleasant, -7 or -8

Example 7: Neither, no rating

Example 8: Neither, no rating

Example 9: Neither, no rating

THE EXAMPLES WERE REVIEWED BY THE RATERS AS MANY TIMES AS NEEDED TO ENSURE THAT THE RATERS UNDERSTOOD THE RATINGS GIVEN FOR EACH TRIAL

Training Session, Part II

"Now I'm going to ask you to make some practice ratings of subjects' prompted expressions to odors. This is to familiarize you with the procedures used during these sessions, as well as to ensure that you understand what I'm asking you to do. As before, ratings for each trial will be recorded on separate pieces of paper."

"For each trial, I will first ask you to determine if a subject finds an odor pleasant, unpleasant or neither pleasant nor unpleasant. You'll indicate this by circling your choice (i.e., P, U, N). If you think the person is smelling an odor which is either pleasant or unpleasant, I'd like you to rate hedonic intensity (that is, how pleasant or unpleasant they find it) by using the 21-point scale, circling the appropriate number."

"Each trial will be presented to you for ten seconds. All subjects were instructed to make the expression after they smelled the odor; therefore, you should base your judgment on the response made after the odor strip has been removed. You should pay no attention to a response made while the subject is smelling the odor or immediately afterward. I want you to wait until I say, 'Go ahead' (i.e., the end of the trial), to make your ratings. You will then have several seconds to record your ratings. For this part of the study, I will strongly encourage you to make a rating for each of these practice trials."

"After you have completed your ratings for each trial, I will ask each of you to tell me what your ratings are for that trial. In this way, you can compare ratings and learn strategies which may assist you in making your ratings. After each trial, I'd like you to discuss the strategies you used to make your decisions. After this discussion is completed, I'll ask you to rate that trial again. I'd like you to take into account strategies discussed by others which may help you in making your ratings when viewing the trial a second time. But, your second rating of the trial should still be based upon what you think."

Training example 1: Unpleasant, -5 OR -6

Training example 2: Neither, no rating

Training example 3: Unpleasant, -6

Training example 4: Pleasant, +2

Training example 5: Unpleasant, -5

Training example 6: Unpleasant, -7 OR -8

Training example 7: Pleasant, +4 OR +5

Training example 8: Unpleasant, -2 OR -3

Training example 9: Neither

Training example 10: Pleasant, +6 OR +7

Training example 11: Pleasant, +5 OR +6

Training example 12: Pleasant, +3

Training example 13: Unpleasant, -4

Training example 14: Neither, no rating

Training example 15: Pleasant, +6 OR +7

ALL 15 TRAINING EXAMPLES WERE SHOWN, USING THE PROCEDURE DESCRIBED ABOVE. RATERS' RESPONSES WERE RECORDED AFTER EACH TRIAL. COMMENTS AND STRATEGIES USED FOR EACH TRIAL WERE ALSO RECORDED.

ESTABLISHING INITIAL INTER-RATER RELIABILITY

"Now I'll ask you to rate some other trials. For each trial, you will be asked to make both ratings. Please wait until the end of the trial to make your ratings. You will then have ten seconds to complete your ratings. From now on, you cannot review any trial. You are strongly encouraged to rate each trial even if you feel as if you're guessing. But, if you feel

that you cannot make a rating for a particular trial, please circle "cannot judge" for that particular rating, and try to rate whatever you feel you can for that trial. After completing your ratings, turn over the page and wait for the next trial. I will tell you what trial number we are on to ensure that everyone is on the correct page when making the ratings. As these ratings are to be made independently, please do not discuss your ratings amongst yourselves. Does anyone have any questions?"

APPENDIX 5

Results from the Control Measures

Group Comparisons

A series of factorial or one-way ANOVAs were conducted for each control measure. Performance on the Smell Identification Test as a function of Group and Nostril (3 X 2) was compared by a mixed design, repeated measures ANOVA; an additional analysis was completed on a subset of RHD and LHD subjects to examine intrahemispheric effects. For all other measures, one-way ANOVAs were done to examine effects of Group. Newman-Keuls multiple comparison procedures were used when making post-hoc comparisons.

Buccofacial Apraxia. Means and standard deviations for each group on measures of accuracy and ease of execution are reported in Table 57. For **accuracy**, there was a significant effect for Group ($F = 8.53$; $df = 2,55$; $p < .01$). Using post-hoc tests, LHDs ($M = .73$) were significantly less accurate in performing facial movements than either RHDs ($M = .91$) or NCs ($M = .94$). For **ease of execution**, there was also a significant Group effect ($F = 9.83$; $df = 2,55$; $p < .01$). Post-hoc analyses again revealed that LHDs ($M = 2.49$) performed more poorly in terms of execution of movements than either RHDs ($M = 2.74$) or NCs ($M = 2.90$).

Facial Paralysis. Direction and extent of facial paralysis were analyzed for each face part (i.e., whole face, lower face, and upper face). Means and standard deviation for these measures as a function of face part and group are shown in Table 57.

For **direction**, negative scores are indicative of greater right facial paralysis, and positive scores are indicative of greater left facial paralysis. For the face as a whole, there was a significant Group effect ($F = 16.38$; $df = 2, 55$; $p < .01$). The three groups were significantly different from each other, with LHDs ($\underline{M} = -.15$) having greater right facial paralysis and RHDs having greater left facial paralysis ($\underline{M} = .19$), in comparison to NCs (-.02). Similar results for Group were seen for analyses comparing direction of paralysis in the lower face ($F = 17.27$; $df = 2,55$; $p < .01$). Again, the three groups were significantly different from each other, with results for direction for the lower face similar to that for the whole face. Mean scores for direction of paralysis for the lower face for LHDs, RHDs, and NCs were, respectively, -.30, .31, and -.01. For direction of paralysis in the upper face, there was no difference between the Groups ($F = 1.76$; $df = 2,55$; $p = .18$).

Table 57. Scores on Measures of Buccofacial Apraxia and Facial Paralysis as a Function of Group

Measure	Group					
	LHD		RHD		NC	
	Mean	(sd)	Mean	(sd)	Mean	(sd)
Buccofacial Apraxia						
Accuracy	.73	(.26)	.91	(.10)	.94	(.09)
Ease of Execution	2.49	(.46)	2.74	(.15)	2.90	(.16)
Facial paralysis						
Direction of Paralysis						
Whole Face	-.15	(.22)	.19	(.22)	-.02	(.09)
Lower Face	-.29	(.36)	.31	(.37)	-.01	(.19)
Upper Face	.00	(.14)	.07	(.15)	-.02	(.17)
Extent of Paralysis						
Whole Face	.53	(.25)	.50	(.23)	.34	(.13)
Lower Face	.61	(.32)	.59	(.36)	.36	(.15)
Upper Face	.44	(.33)	.40	(.23)	.31	(.17)

When **extent** of facial paralysis in the whole face was considered, there was a significant effect of Group ($F = 4.18$; $df = 2,55$; $p = .02$). The degree of paralysis for the LHDs ($\underline{M} = .53$) and RHDs ($\underline{M} = .50$) was significantly greater than in NCs ($\underline{M} = .34$), with no difference between the two BD groups. For the lower face, there was again a significant Group effect ($F = 4.14$; $df = 2, 55$; $p = .02$). As before, LHDs ($\underline{M} = .61$) and RHDs ($\underline{M} = .59$) had greater degree of paralysis in the lower face than NCs ($\underline{M} = .34$), but the BD groups did not differ from each other. No Group differences emerged for extent of paralysis in the upper face ($F = 1.17$; $df = 2, 55$; $p = .32$).

Smell Identification Test. Results of these analysis are shown in Tables 58 and 59, showing the mean percent scores for each nostril as a function of Group and the findings from the ANOVA, respectively. Results indicated a significant effect of Group. Here, both LHDs ($\underline{M} = 73.21$) and RHDs ($\underline{M} = 68.74$) were poorer at identifying the odors than the NCs ($\underline{M} = 84.5$). A trend was observed for the Group X Nostril interaction. When odors were presented to the left nostril, olfactory identification performance for both LHDs and RHDs were poorer at identifying odors than controls. However, when odors were presented to the right nostril, RHDs were poorer at identifying odors and NCs and LHDs.

Another ANOVA was done comparing intrahemispheric effects on olfactory identification abilities, controlling for months post onset. These means and standard deviations and ANCOVA results are presented in Tables 60 and 61. As shown, there was no significant effect of lesion site (e.g., anterior + posterior, posterior only) on the subjects' ability to identify the odorants.

Table 58. Average Percent Scores on the Smell Identification Test as a Function of Nostril and Group

	Group					
Measure	LHD		RHD		NC	
	Mean	(sd)	Mean	(sd)	Mean	(sd)
Right Nostril	75.3	(13.8)	65.2	(19.5)	83.1	(11.7)
Left Nostril	70.8	(15.6)	71.9	(16.4)	85.6	(13.2)

Table 59. Analysis of Variance for the Smell Identification Test

Source	df	F	p value
Between subjects			
Group (G)	2	6.88	.002
S within-group error	55	(363.62)	
Within subjects			
Nostril (N)	1	.64	.43
G X N	2	2.86	.07
N X S within-group error	55	(109.76)	

Note. Values in parentheses represent mean square error.

Table 60. Average Percent Scores on the Smell Identification Test as a Function of Nostril, Group and Lesion Site

Measure	Group							
	LHDa+p		LHDp only		RHDa+p		RHDp only	
	Mean	(sd)	Mean	(sd)	Mean	(sd)	Mean	(sd)
Right Nostril	74.4	(16.7)	74.4	(13.5)	62.5	(24.4)	68.8	(18.3)
Left Nostril	70.0	(16.7)	70.0	(17.7)	70.0	(13.6)	71.3	(20.7)

Table 61. Intrahemispheric Effects for Performance on the Smell Identification Test

Source	df	F	p value
Between subjects			
Group (G)	1	.53	.47
Lesion Site (LS)	1	.11	.74
G X LS	1	.11	.74
S within-group error	28	(493.64)	
Within subjects			
Nostril (N)	1	.01	.92
G X N	1	2.24	.15
LS X N	1	.16	.69
G X LS X N	1	.16	.69
N X S within-group error	28	(157.03)	

Note. Values in parentheses represent mean square errors.

Cognitive Measures. Group performances for most of the cognitive measures (i.e., DRS Memory and Attention Scales; BDAE Commands and Reading Sentences and Paragraphs subtests) were examined by using percentile scores. In terms of the WAIS-R, the 3 groups were compared on age-scaled scores on the WAIS-R subtests. For the LHDs, performance on the Block Design subtest was used, whereas performance on the Information subtest was used for the RHDs. An average of these two tests were obtained for the NCs. In this manner, performances of the 3 groups on the WAIS-R were compared. Performances on all cognitive measures are summarized in Table 62.

For the DRS, significant Group effects were found on overall performance for both the Attention Scale ($F = 3.08$; $df = 2,53$; $p = .05$) and the Memory Scale ($F = 4.17$; $df = 2,54$; $p = .02$). On the former Scale, RHDs ($M = 42.4$) performed significantly more poorly than NCs ($M = 64.2$), but no worse than LHDs ($M = 48.6$); on the latter Scale, LHDs ($M = 40.0$) performed significantly worse than NCs ($M = 63.5$), but no worse than RHDs ($M = 46.8$). A

one-way ANOVA on the WAIS-R subtest(s) revealed no significant Group differences (F = .66; df = 2,55; p = .52). Performances on the BDAE subtests also did not differ between the 3 groups (Commands: [F = 1.87; df = 2,50; p = .17]; Reading Sentences and Paragraphs: [F = 1.88; df = 2,50; p = .16]).

Table 62. Performance on Cognitive Screening Measures as a Function of Group

Measure	Group					
	LHD		RHD		NC	
	Mean	(sd)	Mean	(sd)	Mean	(sd)
DRS Attention Scale*	48.6	(28.6)	42.3	(30.5)	64.2	(20.4)
DRS Memory Scale*	38.9	(30.2)	46.8	(26.5)	63.5	(20.7)
WAIS-R Age Scaled Performance **	10.4	(3.4)	11.2	(3.3)	11.5	(2.7)
BDAE Commands +	39.1	(34.4)	40.7	(31.7)	58.2	(22.3)
BDAE Reading Sentences & Paragraphs	39.7	(33.1)	53.0	(29.1)	59.4	(28.1)

Note. * DRS: Dementia Rating Scale Subscales (percentile scores)
** WAIS-R age scaled scores: LHDs (Block Design subtest); RHDs (Information subtest); NCs (average of Block Design and Information subtests)
+ BDAE: Boston Diagnostic Aphasia Examination subtests (percentile scores)

Relationship between Control, Experimental and Facial Expression Measures

A series of Spearman rank order correlations were completed comparing performance on control measures to the experimental measures, to determine if it was necessary to take into account group differences on the control measures when analyzing results from the experiment proper and posed expressions produced without odors. These analyses were completed only on control tasks where significant group differences emerged, which included accuracy and execution of facial movements (buccofacial apraxia), extent of whole facial paralysis, performance on the Smell Identification Test, and performance on DRS Attention and Memory Scales. Direction of facial paralysis was not needed as a control measure, as facial asymmetries was not being examined in the current study. The former measure would

be important to control for if facial asymmetries in hedonic expressions were being examined in the current study.

The relationships between control and experimental measures were examined on a group-by-group basis. From the experiment proper, the measures of responsivity, accuracy and intensity (Conditions 1, 2, 3 and 5), and presence of an avoidance response (Conditions 1 and 5) were examined separately as a function of both valence (pleasant vs unpleasant odors) and nostril (left vs right). For the behavioral choice measure (Condition 4), number of pleasant odors chosen was used. If any of the experimental and control measures correlated beyond chance levels, than differences in group performances on the control measures were used as a covariate when analyzing effects from the experiment proper. The relationships are examined and discussed in terms of the different experimental conditions.

a.) Spontaneous Facial Expressions to Odors (Condition 1)

Relationship to Facial Movement Measures. The 16 experimental measures were correlated to the two measures of buccofacial apraxia. Among the 96 correlations computed (32 rhos X 3 subject groups), only 4 were significant, which was not more than would be expected by chance.

Relationship to Extent of Facial Paralysis. The experimental measures were correlated to degree of paralysis for the whole face. For the 48 correlations computed (16 X 3), none were significant.

Relationship to the Smell Identification Test. The experimental measures were correlated to overall percent correct performance, as well as to percent correct performance for odors presented to the left and right nostril. For the 144 correlations computed (48 X 3),

14 were significant for the LHD and NC groups; for the RHDs, no significant correlations were found.

For the LHDs, overall performance on the SIT negatively correlated to the following measures: left unpleasant responsivity (rho = -.48); left unpleasant accuracy (rho = -.49); and left unpleasant intensity (rho = -.43). Olfactory identification performance for the right nostril for this group also negatively correlated to: left unpleasant responsivity (rho = -.52); left unpleasant intensity (rho = -.45); and right unpleasant accuracy (rho = -.47).

For the NCs, overall SIT performance positively correlated to: left unpleasant accuracy (rho = .48); left unpleasant intensity (rho = .53); and right unpleasant accuracy (rho = .51). For SIT performance for the right nostril, positive correlations were found for left unpleasant accuracy (rho = .51) and left unpleasant intensity (rho = .52). For SIT performance for the left nostril, significant correlations were found for left unpleasant intensity (rho = .49), right pleasant intensity (rho = -.50) and right unpleasant accuracy (rho = .67).

Relationship to Cognitive Measures (DRS Scales). Among the 96 (32 X 3) correlations computed , 9 were significant for the LHD and NC groups; no significant correlations emerged for the RHD group.

For the LHDs, performance on the Memory Scale was inversely correlated to scores on left pleasant avoidance (rho = -.47), right pleasant intensity (rho = -.49) and right unpleasant responsivity (rho = -.49). For the Attention Scale, a positive correlation was obtained for left unpleasant accuracy (rho = .54).

For the NCs, performance on the Memory Scale was positively correlated to the following measures: left unpleasant accuracy (rho = .51); left unpleasant responsivity (rho =

.50); right unpleasant accuracy (rho = .47) and right unpleasant intensity (rho = .61). An inverse relationship was seen between performance on the Memory Scale and right pleasant intensity (rho = -.47).

b.) Spontaneous Expressions to Highly Unpleasant Odors (Condition 5)

Relationship to Facial Movement Measures. Among the 48 (16 X 3) correlations computed, none were significant.

Relationship to Extent of Facial Paralysis. Degree of facial paralysis in the whole and lower face was examined. For the 96 (32 X 3) correlations computed, 4 were significant, which again is what would be expected by chance.

Relationship to Smell Identification Test. As for Condition 1, the experimental measures were correlated to overall performance on the SIT, as well as performances for the left and right nostril. Among the 144 (48 X 3) correlations computed, only 4 were significant, which was not beyond chance levels.

Relationship to Cognitive Measures (DRS Scales). Here, 96 (32 X 3) correlations were computed. Only 3 correlations were significant, which is at the level expected by chance.

c.) Prompted Expressions to Odors (Condition 2)

Relationship to Facial Movement Measures. The 12 experimental measures were correlated to the 2 measures of buccofacial apraxia. Among the 72 (24 X 3) correlations computed, none were significant.

Relationship to Extent of Facial Paralysis. The experimental measures were correlated to degree of paralysis for the whole face. Among the 36 (12 X 3) correlations computed, there was one significant finding, which was not more than would be expected by chance.

Relationship to Smell Identification Test. Among the 108 (36 X 3) correlations computed, 10 were significant. Significant correlations were found only for the RHD group. For the RHDs, overall performance on the SIT was positively correlated to the following measures: left pleasant accuracy (rho = .55); left unpleasant intensity (rho = .66); left unpleasant responsivity (rho = .49); right pleasant accuracy (rho = .49); and right unpleasant intensity (rho = .52). Percent correct performance for the left nostril was associated with left (rho = .57) and right (rho = .46) unpleasant intensity scores. Percent correct performance for the right nostril was positively associated with left pleasant accuracy (rho = .51), left unpleasant intensity (rho = .58) and right unpleasant intensity (rho = .50).

Relationship to Cognitive Measures (DRS Scales). Among the 72 (24 X 3) correlations computed, 2 findings were significant, which was not beyond levels expected by chance.

d.) Subjective Ratings to Odors (Condition 3)

Relationship to Smell Identification Test. The 12 experimental measures were correlated to overall performance (percent correct) on the SIT, as well as percent correct performance for the left and right nostrils. Among the 108 (36 X 3) correlations computed, 13 findings were significant. Overall olfactory identification performance was positively correlated to the following measures: (1) for LHDs, to right unpleasant accuracy (rho = .50) and right unpleasant responsivity (rho = .63); (2) for RHDs, to right pleasant responsivity

(rho = .54); and (3) for NCs, to left unpleasant intensity (rho = .54) and right pleasant responsivity (rho = .46).

Positive relationships were also seen for olfactory identification scores for odors presented to the left nostril. This measure was correlated to right unpleasant accuracy (rho = .45) and right unpleasant responsivity (rho = .60) for LHDs, and to right unpleasant responsivity (rho = .50) for NCs.

Lastly, SIT scores for odorants presented to the right nostril were correlated to the following measures: (1) for LHDs, to right unpleasant responsivity (rho = .65); (2) for RHDs, to right pleasant responsivity (rho = .45); and (3) for NCs, to left pleasant responsivity (rho = .46), left unpleasant intensity (rho = .59), and right pleasant responsivity (rho = .48).

Relationship to Cognitive Measures (DRS Scales). Of the 72 (24 X 3) correlations computed, 4 findings were significant, which was what would be expected by chance.

e.) Behavioral Choice Measure (Condition 4)

Relationship to Smell Identification Test. The two experimental measures were correlated to overall performance on the SIT, as well as percent correct performance for left and right nostrils. Among the 18 (6 x 3) correlations computed, 4 were significant. For the LHDs, choice measures for the left nostril were associated with left nostril SIT performance (rho = .47). For the RHDs, choice measures for the right nostril were associated with overall SIT performance (rho = .67), with left nostril SIT performance (rho = .66) and with right nostril SIT performance (rho = .48).

Relationship to Cognitive Measures (DRS Scales). Of the 12 (4 x 3) correlations computed, none were significant.

f.) Posed Hedonic Expressions without Odors

Relationship to Facial Movement Measures. The 6 experimental measures were correlated to the 2 measures for buccofacial apraxia. Of the 36 correlations (12 x 3) computed, none were significant.

Relationship to Extent of Facial Paralysis. The extent of paralysis in the whole face was correlated to the experimental measures. Of the 18 correlations (6 X 3) computed, one was significant, which is not greater than that expected by chance.

g.) Posed Facial Expressions to Six Discrete Emotions

Relationship to Facial Movement Measures. The 3 experimental measures were correlated to the 2 measures for buccofacial apraxia. Of the 18 correlations (6 x 3) computed, 3 were significant. For the LHDs, a significant relationship to accuracy in posing emotional expressions was found for both correctness of non-emotional facial movement (rho = .50) and extent of apraxia (rho = .53). For RHDs, accuracy in posing emotional expressions was correlated to correctness of non-emotional facial movment (rho = .54). No significant correlations were found for the NC group.

Relationship to Extent of Facial Paralysis. The extent of paralysis in the whole face was correlated to the experimental measures. Of the 9 correlations (3 X 3) computed, none were significant.

Relationship Between Months Post Onset and Experimental Measures

In addition to the correlations above, the relationship between months tested since stroke onset (MPO) and the experimental measures was examined, using Spearman rank order

correlations. When group differences were studied, MPO was greater in individuals with anterior plus posterior lesions compared to those with posterior only lesions (see Methods section, "Description of LHD and RHD Groups"). Since intrahemispheric effects were examined for the LHD and RHD group, MPO was correlated to each dependent measure for four of the odor conditions, as MPO may have influenced performance on the experimental tasks. As before, the relationship between MPO and the experimental measures (i.e., responsivity, accuracy, intensity, presence of an avoidance response, and number of pleasant odors chosen) were examined for LHDs and RHDs independently, and when appropriate, the analyses for the experimental measures were conducted separately for both valence and nostril.

a.) Spontaneous Facial Expressions to Odors (Condition 1). Of the 32 correlations computed (16 X 2), two were significant, which was not greater than that expected by chance alone.

b.) Prompted Facial Expressions to Odors (Condition 2). For this condition, 24 correlations were computed (12 X 2), with four correlations being significant. For the LHDs, MPO negatively correlated with left unpleasant responsivity (rho = -.45), left pleasant intensity (rho = -.45) and right pleasant responsivity (rho = -.60). For the RHDs, one positive correlation was found, with MPO correlating with left pleasant intensity (rho = .49).

c.) Subjective Ratings of Odors (Condition 3). Of the 24 correlations computed (12 X 2), one was significant, which was not greater than that expected by chance.

d.) Behavioral Choice Measure (Condition 4). For this condition, of the four correlations computed (2 X 2), none were significant.

APPENDIX 6

Additional Analyses for Facial Expressions to Six Discrete Emotions

As significant group differences emerged for this condition, additional analyses were conducted to compare group performances for each emotion. Mixed design repeated measure ANOVAs were done for the measures of confidence ratings and intensity of facial expressions, with Group (3 levels) as a between subjects variable and Emotion (6 levels) as a within subject variable. For accuracy, a mixed design repeated measure ANCOVA was done, with the two measures from the buccofacial apraxia tasks used as covariates. For post-hoc comparisons, the Hayter-Fisher LSD procedure was used for pairwise comparisons (see Ramsey, 1995). As there were six levels for Emotion, it was decided that the Newman-Keuls procedure did not provide sufficient protection against experimentwise error rate, as more than three comparisons were made (Zwick, 1993).

For accuracy, there was a significant main effect for Group ($F[2, 49] = 5.36$, $p = .008$) and Emotion ($F[5,255] = 20.27$, $p < .001$), but not for the interaction between Group and Emotion ($F[10,255] = .92$, $p = .52$). For Group, post-hoc comparisons on adjusted means revealed that, as discussed in the Results section, expressions produced by RHDs ($M = .44$) were rated significantly less accurately than NCs ($M = .60$), with no differences emerging between these two groups and LHDs ($M = .56$). These mean values are different from those reported in the Results, as five poses from four subjects were lost due to videorecording difficulties, thus altering mean values. Means and standard

deviations for each Group and for the groups combined for each type of emotion are shown in Table 63.

Table 63. Unadjusted Means of Main and Interaction Effects as a Function of Emotion for Accuracy for Facial Expressions to Six Discrete Emotions

Group	Emotion											
	Happy		Sad		Anger		Fear		Disgust		Surprise	
	Mn	(s.d.)	Mn	(s.d.)	Mn	(s.d.)	Mn	(s.d.)	Mn	(s.d.)	Mn	(s.d.)
All Groups	**.85**[a]	(.27)	**.69**[b]	(.35)	**.44**[c]	(.37)	**.29**[a,b]	(.31)	**.42**[a]	(.41)	**.53**[a]	(.37)
LHD	.87	(.29)	.53	(.40)	.46	(.37)	.21	(.29)	.44	(.45)	.51	(.42)
RHD	.78	(.30)	.70	(.34)	.31	(.39)	.24	(.25)	.29	(.34)	.47	(.35)
NC	.89	(.21)	.84	(.23)	.58	(.30)	.46	(.35)	.53	(.42)	.64	(.33)

Note: Findings discussed in text are highlighted in the Table.
Letters in superscript represent significant post-hoc comparisons.

Post hoc comparisons for Emotion revealed that raters were significantly more accurate in rating Happy expressions in comparison to all other expressions (Fear, Disgust, Anger and Surprise) except for Sadness. Raters were also more accurate in rating Sad expressions in comparison to expressions of Fear. No other comparisons were significant.

For confidence ratings, there were significant effects for Group ($F[2,51] = 8.73$, $p = .001$), Emotion ($F[5,255] = 20.02$, $p < .001$) and Group by Emotion ($F[10,255] = .029$, $p = .03$). Mean values for each Group and for the Groups combined as a function of each emotion are shown in Table 64.

Table 64. Unadjusted Means of Main and Interaction Effects as a Function of Emotion for Confidence Ratings for Facial Expressions to Six Discrete Emotions

Group	Emotion											
	Happy		Sad		Anger		Fear		Disgust		Surprise	
	Mn	(s.d.)	Mn	(s.d.)	Mn	(s.d.)	Mn	(s.d.)	Mn	(s.d.)	Mn	(s.d.)
All Groups	3.31	(1.09)	2.34	(.78)	2.45	(.78)	2.23	(.71)	2.50	(.85)	2.44	(.79)
LHD	3.62	(.87)	2.25	(.75)	2.62	(.94)	2.13	(.53)	2.44	(.80)	2.31	(.71)
RHD	2.60	(1.12)	2.12	(.63)	2.10	(.59)	1.85	(.53)	2.21	(.77)	2.27	(.83)
NC	3.79	(.87)	2.67	(.90)	2.68	(.67)	2.80	(.73)	2.87	(.88)	2.79	(.74)

Post-hoc comparisons were conducted to explore the significant Group by Emotion interaction. For Anger and Happiness, raters were significantly less confident in rating the RHDs' expressions than expressions produced by both LHDs and NCs. For Sadness, Fear, Disgust and Surprise, raters were less confident in rating both RHDs' and LHDs expressions in comparison to NCs, with no group differences emerging between the two lesion groups. These group differences for each emotion are also depicted in Figure 2.

When within-group comparisons were explored for each group, post-hoc comparisons revealed that raters were significantly more confident in rating expressions of happiness in comparison to all other emotions (fear, sadness, surprise, anger, disgust) for both the LHD and RHD group. For RHDs, raters were only more confident in rating these posers' expressions of happiness in comparison to expressions of fear.

For intensity, there were significant effects for Group ($F[2,51] = 3.27$, $p = .05$), Emotion ($F[5,255] = 20.02$, $p < .001$), and for Group by Emotion ($F[10,255] = 3.17$, $p = .001$). Means and standard deviations for intensity for the three groups and all groups combined for each emotion are shown in Table 65.

Table 65. Means of Main and Interaction Effects as a Function of Emotion for Ratings of Intensity for Facial Expressions to Six Discrete Emotions

Group	Emotion											
	Happy		Sad		Anger		Fear		Disgust		Surprise	
	Mn	(s.d.)	Mn	(s.d.)	Mn	(s.d.)	Mn	(s.d.)	Mn	(s.d.)	Mn	(s.d.)
All Groups	3.61	(1.35)	2.34	(.82)	3.08	(1.09)	3.05	(1.16)	3.22	(1.22)	3.23	(.97)
LHD	3.84	(1.10)	2.48	(.94)	2.98	(1.23)	2.77	(.96)	3.45	(1.33)	3.11	(.92)
RHD	3.00	(1.33)	2.20	(.80)	2.96	(1.14)	2.58	(.98)	2.95	(1.29)	2.93	(.97)
NC	4.06	(1.43)	2.31	(.73)	3.32	(.86)	3.93	(1.13)	3.59	(.96)	3.70	(.90)

Post-hoc comparisons were completed to compare group differences for each emotion. For Happiness and Disgust, expressions of the RHDs were rated as being significantly less intense than expressions made by the LHDs and NCs, with no differences emerging between LHDs and NCs. For Fear and Surprise, expressions by the RHDs and LHDs were rated as being significantly less intense than NCs, with no differences emerging between the two lesion groups. For Disgust, the RHDs' expressions were rated as being significantly less intense than the NCs, with no significant differences emerging between LHDs and NCs or RHDs. No significant differences between Groups emerged for intensity for Sadness or Anger. These differences are shown in Figure 3.

Within-group comparisons were also completed to explore the intensity of expressions for each emotion produced by each group. For LHDs, expressions of happiness were rated as being significantly more intense than the other five emotions. In addition, expressions of sadness were rated as being significantly less intense than expressions made for surprise and disgust. No other comparisons were significant for the LHD group. For the RHDs, expressions of sadness were rated as being significantly less intense for four emotions (surprise, anger, disgust, happiness) except for fear. Lastly, for

NCs, expressions of sadness were rated as being significantly less intense than all other emotions. In addition, expressions of anger were rated as being less intense than expressions of fear and happiness.

Figure 2. Group Differences for Confidence Ratings as a Function of Each Emotion for Facial Expressions to Six Discrete Emotions.

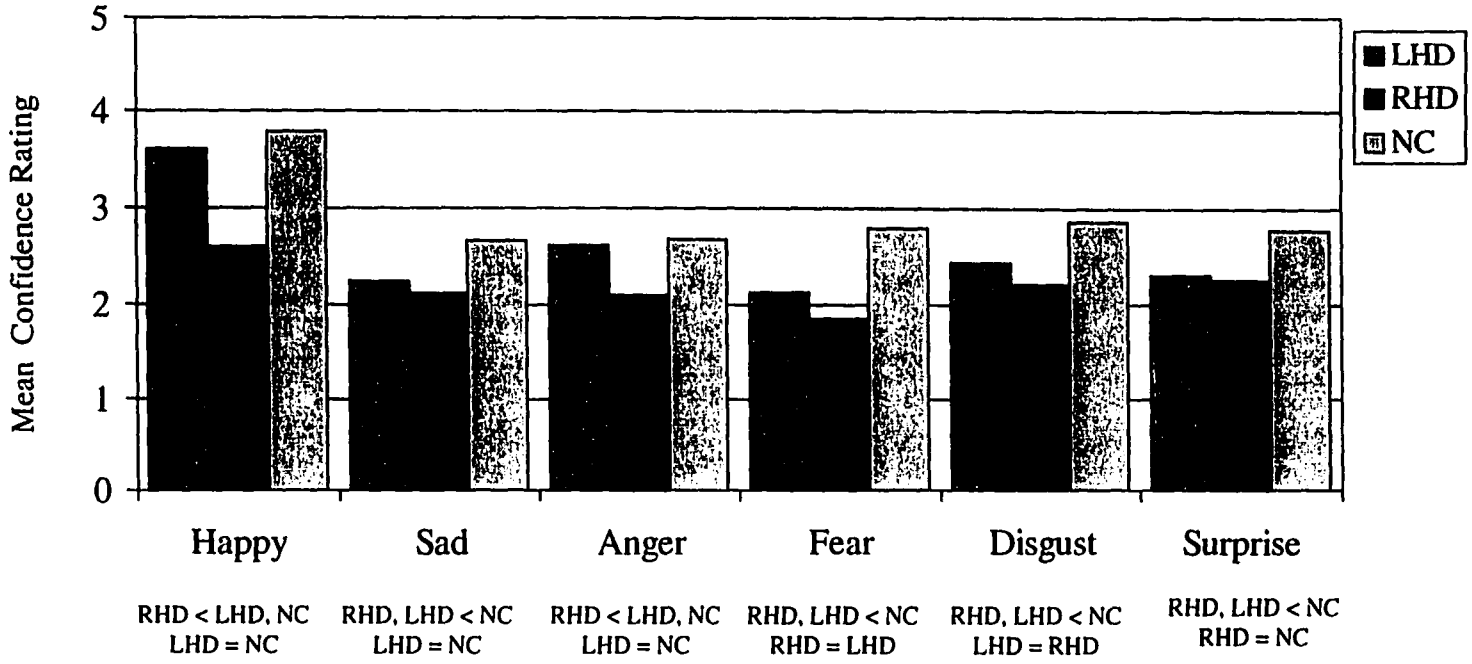
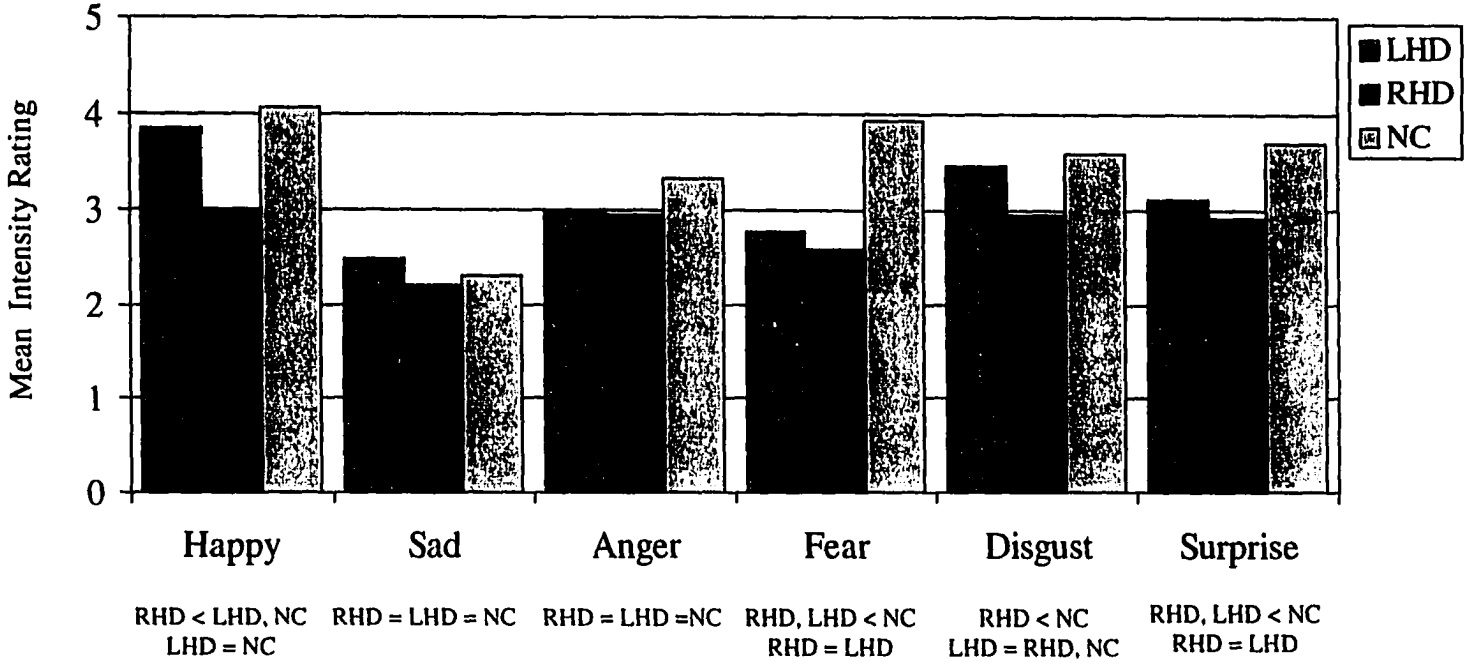


Figure 3. Group Differences for Ratings of Intensity as a Function of Each Emotion for Facial Expressions to Six Discrete Emotions.



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