Vallar G (1993). The anatomical basis of spatial hemineglect
  in humans. In: IH Robertson, JC Marshall (Eds.), Unilat-
  eral Neglect: Clinical and Experimental Studies. Lawrence
  Erlbaum, Hove, UK, pp. 27–59.
Wapner W, Judd T, Gardner H (1978). Visual agnosia in an
  artist. Cortex 14: 343–364.

Watson JD, Myers R, Frackowiak RS, et al. (1993). Area V5
  of the human brain: Evidence from a combined study using
  positron emission tomography and magnetic resonance
  imaging. Cereb Cortex 3: 79–94.
Zeki SM (1990). A century of cerebral achromatopsia. Brain
  113: 1721–1177.

Chapter 25

Laboratory testing of emotion and frontal cortex

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25.1. Introduction

Modern neuropsychological testing is based on a
highly differentiated model of cognitive functioning
in which deficits can appear in any of a number of pro-
cesses (e.g., memory, executive function, computation,
attention). Moreover, many of these processes can be
further broken down into subprocesses that can also
be assessed (e.g., short-term, long-term, and working
memory).

The state of affairs is much less advanced for testing
emotional functioning. As with cognition, there are
compelling theoretical, empirical, and anatomical rea-
sons to consider the emotion system as consisting of a
number of different processes and subprocesses. How-
ever, there are relatively few tests available for asses-
sing emotional functioning and, among those, the
relationship with specific emotion processes is often
not well articulated. In fact, in many neuropsychological
batteries, only a single emotion process is tested (e.g.,
the ability to recognize the emotion being expressed in
a photo of a facial expression). In our view, extrapola-
tions about overall emotional functioning based on test-
ing a single emotional process can be very misleading.

This chapter begins with a discussion of what we
consider most critical for a comprehensive assessment
of emotional functioning and then describes the assess-
ment procedures we use. Because our work is primarily
conducted in the laboratory, our procedures are designed
for that environment. In recent years we have used these
procedures with hundreds of patients with neurodegen-
erative diseases (frontotemporal lobar degeneration,
Alzheimer's, amyotrophic lateral sclerosis), congenital
neurological diseases (Moebius syndrome), and focal
lesions (orbitofrontal), as well as with neurologically

normal controls. We consider the laboratory to be an
excellent test bed for developing, refining, and evaluating
assessment techniques. Those techniques that prove most
useful can then be translated into forms more appropriate
for use in the clinic and at the bedside.

25.2. Emotion

Definitions of emotions vary in terms of their emphasis
on biological features, cognitive features, appraisal pro-
cesses, motor action patterns, expressive behavior, lan-
guage, and coping. The way that emotion is defined
significantly influences the design of the assessment
battery necessary to assess emotional functioning. The
definition we have proposed emphasizes the adaptive,
organizing function of emotion: 'Emotions are short-
lived psychological–physiological phenomena that
represent efficient modes of adaptation to changing
environmental demands.' (Levenson, 1994, p. 123).

For us, emotion serves a number of functions, alter-
ing attention, adjusting behaviors upward and down-
ward in response hierarchies, and activating relevant
associative networks in memory. An important function
of emotion is to organize numerous biological systems
(including facial expression, somatic muscles, voice
tone, autonomic nervous system, endocrine system) into
a bodily milieu that is optimal for effective response.
Emotions serve important social functions, moving us
toward certain people and away from others. Reflecting
this view, our laboratory assessment of emotional func-
tioning focuses on brief emotional phenomena (not
on longer moods) and on the activation of multiple
response systems (not on a single system such as verbal
report of emotional experience). Moreover, it includes
assessment of emotion in interpersonal contexts.

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25.3. Emotion processes

We believe that three emotional processes should be included in any comprehensive assessment of emotional functioning: (a) emotional reactivity, (b) emotional regulation, and (c) emotional understanding. Emotional reactivity refers to the type, magnitude, and duration of response that occurs in reaction to changes in the internal and external environment that have significance for our goals and wellbeing. Emotional regulation refers to the adjustments in type, magnitude, and duration of emotional response that are made to meet personal goals and situational demands. Emotional understanding refers to the recognition of emotions in self and others, and to the understanding of why these emotions have occurred and what their consequences may be. We believe that each of these processes is subserved by different neural circuitry, and thus can be differentially impacted by injury and disease.

25.3.1. Emotional reactivity

Emotional reactivity is usually operationalized in terms of the type, magnitude, and duration of response. In the laboratory, emotional reactivity is typically assessed by presenting the individual with a standardized stimulus thought to elicit emotion in most people (e.g., viewing a film of a child mourning the death of his father) or a personally meaningful stimulus (e.g., remembering the death of one's own parent) and then measuring the reaction in one or more emotional response systems (see below).

It is our belief that emotional reactivity can only be assessed accurately in vivo, that is, as emotions are actually produced. Procedures in which individuals are asked to indicate the emotional responses they think they would have or have had in particular situations measure different processes (e.g., emotional self-knowledge, knowledge of normative responses) and are prone to biased and erroneous reports.

25.3.2. Emotional regulation

Gross (1998, p. 275) defines emotional regulation as:

...the processes by which individuals influence which emotions they have, when they have them, and how they experience and express these emotions. Emotion regulatory processes may be automatic or controlled, conscious or unconscious, and may have their effects at one or more points in the emotion generative process.

Perhaps because the term 'emotional regulation' is so closely associated with reining in emotions, it is easy to think of emotional regulation as being limited to emotional inhibition or suppression. However, it is clear that emotional regulatory competence also involves the ability to amplify or exaggerate emotion in situations where the emotional signal to conspecifics must be clear and unambiguous.

Often emotional reactivity and regulation are difficult to separate. Take, for example, a situation in which a patient exhibits a very small behavioral response to a highly stressful film. Is this patient showing a low level of emotional reactivity or a high level of emotional regulation? The difficulty of making this distinction underscores the value of assessing the individual's capacity to regulate emotion when instructed to do so. This capacity to regulate on demand can be determined with some certainty, whereas assessing the emotional regulation that occurs spontaneously will always be difficult to separate completely from emotional reactivity.

25.3.3. Emotional understanding

Emotional knowledge takes a number of forms, ranging from the relatively simple (e.g., knowledge about whether or not we or others are experiencing emotion), to the more differentiated (e.g., knowledge about the particular emotion and intensity of emotion being experienced), to the highly complex (e.g., theories of emotion and emotional regulation, metacognitions about emotion, beliefs about the relationships between emotions and other aspects of the human condition such as health, wellbeing, and relationship stability).

We consider the basic building block of emotional understanding to be empathic accuracy—the ability to know what another person is feeling. This can be assessed in its simplest form by having people identify which particular emotion is shown in a photograph. Two common tests of this sort are the Florida Affect Battery (Bowers, 1992) and the Facial Expressions of Emotion (Young et al. 2002). The Florida Affect Battery also has sections in which emotions are identified from tone of voice (prosody).

More complex, and arguably more ecologically valid assessments of emotional understanding involve using dynamic stimuli in which the emotional content unfolds over time and is embedded in a meaningful social context. Examples of these more dynamic stimuli include films (Gross and Levenson, 1995) and observed social interactions (Levenson and Ruef, 1992).

25.4. Emotion types

There are three broad categories of emotion that should be considered when assessing emotional functioning: (a) negative emotions, (b) positive emotions, and (c) self-referential emotions. Most contemporary emotion researchers and theorists do not view emotion as a monolith. Thus, it is no longer tenable to assume that what holds for one type of emotion holds for all types of emotions.

25.4.1. Negative emotions

Negative emotions prepare the organism for dealing with conditions of threat, challenge, and opportunity. Basic negative emotions such as anger, disgust, fear, and sadness are characterized as having different associated patterns of facial expression, motor action, and physiological activation that have been selected through evolution as being most likely to deal successfully with the eliciting condition most of the time (Levenson, 2003). Early theorizing and laboratory studies of emotion often focused almost exclusively on negative emotions, emphasizing such adaptive patterns as 'flight' and 'fight' and their associated patterns of psychological activation.

25.4.2. Positive emotions

Positive emotions were relatively understudied and their functions less well documented until recently. In our work, the role that positive emotions play in calming, soothing, and 'undoing' the physiological effects of negative emotions has been emphasized (Fredrickson and Levenson, 1998; Levenson, 1988). Others have focused on the role positive emotions play in broadening perspectives, increasing flexibility of response, and increasing group cohesion (Fredrickson, 1998; Isen, 1999).

25.4.3. Self-referential emotions

Self-referential emotions involve evaluation of the self with respect to social norms. They can be negatively (e.g., shame, guilt, embarrassment) or positively toned (e.g., pride). These emotions, which require some degree of self-consciousness and self-awareness, appear relatively late in ontogeny and phylogeny.

25.5. Emotion response systems

A comprehensive assessment of emotion should sample from the various systems that constitute the emotional response including: (a) self-reported emotional experience, (b) emotional expressive behavior, (c) peripheral physiology, and (d) emotional language.

25.5.1. Self-reported emotional experience

Self-reported emotional experience can be obtained in a number of different ways. In our laboratory, we ask participants to provide ratings of the intensity of their subjective experience for a list of discrete emotions (e.g., fear, anger, amusement) and dimensions (e.g., pleasantness, arousal) after an emotion-eliciting event. Additionally, we sometimes have participants use a rating dial to indicate how they are feeling (positive–neutral–negative) continuously throughout an emotional experience (Mauss et al., 2005).

25.5.2. Emotional expressive behavior

Emotional expressive behavior is typically quantified by applying objective coding systems to videotapes of participants' emotional behavior. In our laboratory, we use coding systems based either exclusively on facial muscle activity (facial action coding system [FACS]; Ekman and Friesen, 1978) or on multiple indicators including facial expression, tone of voice, and content of speech (Gottman, 1989; Gross and Levenson, 1993). FACS is the most exacting and laborious of these systems, allowing the coder to decompose any observed facial expressions into its component facial muscle actions based on repeated, slow-motion viewing of video recordings.

25.5.3. Peripheral physiology

Peripheral physiology is usually quantified in terms of selected measures of cardiovascular, electrodermal, respiratory, and somatic activity. Timing of measurement is quite important because these systems are often only under the influence of emotion for brief periods before they return to the service of other functions (e.g., homeostasis). In our laboratory, we precede each emotion elicitation with a resting baseline period and then obtain measures continuously throughout the elicitation and during a post-elicitation 'cooling down' period. Analyses focus either on the times during which we attempted to stimulate emotion (e.g., while the participant watches a film) or when we have independent evidence that an emotion has occurred (e.g., when an emotional facial expression appears during an interaction between a patient and caregiver).

25.5.4. Emotional language

Emotional language is often quantified by determining the frequency or proportion of words used in different

categories (e.g., all emotion words, negative emotion words, fear words). A number of computer-assisted approaches can be used that facilitate this kind of text analysis (Mergenthaler, 1985).

A multi-system assessment of emotional functioning has a number of advantages, especially when working with patients for whom measurement of one or more systems may be unreliable (e.g., self-report of subjective experience in aphasic patients). Multi-system assessment is also important when the pathology is thought to affect the organization or coherence among response systems (Mauss et al., 2005).

25.6. Laboratory tests of emotion

25.6.1. Acoustic startle reflex

The acoustic startle reflex is a primitive, defensive response to the threat posed by a sudden loud noise (Sokolov, 1963). It consists of a stereotyped pattern of somatic and facial muscle actions (Ekman et al., 1985) and attendant activation of autonomic nervous system response (Soto et al., 2005). We use a 115 db, 100 ms burst of white noise administered through loudspeakers behind the patient (roughly commensurate with a close proximity gunshot).

We administer the startle under three conditions, which enable us to probe different aspects of emotional functioning. In the unanticipated condition, the startle occurs without warning. This provides a good measure of emotional reactivity to a simple aversive stimulus. In the anticipated condition, the startle is preceded by a 20 s countdown. Because the person knows exactly when it will occur, it provides an opportunity for preparation and thus allows us to assess spontaneous emotional regulation strategies. In the inhibited condition, the startle is preceded by a 20 s countdown and instructions are given to hide reactions; this assesses the capacity to regulate emotion on demand. An exaggerated condition in which instructions are given to increase the visibility of reactions can also be included.

The startle response exists on the boundary between reflex and emotion (Ekman et al., 1985). Although the initial response (typically occurring in the first 500 ms) is quite stereotypical, it is often followed by a secondary response that is a 'response to having been startled,' which varies greatly across individuals. As the person takes stock of what has happened (including his or her reaction to the loud noise) the secondary response can take any of several forms, including amusement, embarrassment, anger, or fear. We have found this secondary response to be quite vulnerable to certain types of brain injury (e.g., dramatically reduced in frontotemporal lobar degeneration; Sturm et al., 2006).

Intact autonomic responding to non-emotional stimuli has been found in the context of frontal lobe injury (Damasio et al., 1990). However, there is evidence that patients with frontal lobe damage (i.e., orbitofrontal damage) show disrupted autonomic responding to emotional and social stimuli (Damasio et al., 1990; Roberts et al., 2004) in spite of normal reactivity to an unanticipated startle stimulus (Roberts et al., 2004). Injury to the frontal lobes (e.g., from head injury or neurodegenerative disease) is likely to also damage the pathways that connect regions of the frontal lobes (e.g., anterior insula) with subcortical structures (e.g., hypothalamus). Although these pathways are thought to be involved in autonomic responding to emotional stimuli, it is unclear if their disruption affects the kind of low-level autonomic reactivity embodied in the startle response (Chu et al., 1997).

25.6.2. Startle eye-blink modulation

The acoustic stimulus used to elicit the startle response described in the previous section is sufficiently loud to activate an intense defensive, whole-body reflex (Sokolov, 1963). An acoustic stimulus of considerably lower amplitude (typically ranging from 95–100 db) will activate a smaller startle reflex (Lang et al., 1990) that can be quantified by electromyographic measurement of the intensity of the associated eye blink. To put this in perspective, a 115 db acoustic stimulus is more than 30 times more powerful than a 100 db stimulus. Unlike the high amplitude startle, the lower amplitude startle does not disrupt ongoing activity and thus can be used as a repeated background 'probe' stimulus while the person is engaged in other activities. The amplitude of the startle eye blink is an indicator of higher cortical functioning such as attentional and emotional processing. In particular it reflects affective valence-positive/approach states attenuate the amplitude of the eye blink and negative/avoidance states have a potentiating effect. Startle eye-blink modulation tests can provide useful information about underlying attentional and emotional state processes without being subject to demand characteristics or voluntary reporting biases (e.g., Bradley and Vrana, 1993). These qualities make them particularly appealing for use with patient populations where self-report might be difficult or unreliable.

Startle eye-blink modulation can be considered in terms of valence match or mismatch. Researchers have proposed that stimuli that elicit positive emotion engage the approach motivational system, while stimuli that elicit negative emotion engage the withdrawal motivational system (Lang, 1994). If a startle probe, an aversive stimulus, is presented while a participant is

experiencing a positive stimulus, there is a valence mismatch between the engaged motivational system and the startle probe, thus the ensuing startle response is attenuated. However, if a negative emotional state is engaged and the startle probe is then presented, the startle response will be augmented. Vrana et al. (1988) found a significant linear relationship between stimulus valence and startle eye-blink amplitude, as evidenced by attenuated startle amplitude when viewing emotionally positive relative to neutral slides, and potentiated startle amplitude when viewing emotionally negative relative to neutral slides. Studies of the temporal course of modulation reveal that the eye-blink amplitude continues to be modulated even after the emotion-eliciting stimulus has been removed (Larson et al., 1998).

25.6.3. Films

Carefully selected excerpts from commercial and other films can be used to elicit emotions. Real-life emotions are often induced by dynamic, external visual and auditory stimuli that unfold over time, thus films have a relatively high degree of ecological validity. Films have been used in laboratory studies for years, going back to their early use to induce diffuse 'stress' responses (e.g., Lazarus et al., 1962).

Gross and Levenson (1995) identified a set of films that elicit the emotions of amusement, anger, contentment, disgust, fear, sadness, and surprise as well as a neutral emotional state. Based on this work, it appears that anger is the most difficult emotion to elicit reliably using short film excerpts. Films have also been found to be useful for producing general positive and negative valenced states (Hubert and de Jong-Meyer, 1990). Film clips lend themselves to the assessment of emotional reactivity (by having participants simply watch the film), emotional regulation (by instructing participants to alter emotional responses), and emotional understanding (by having participants indicate the emotion being experienced by characters in the film).

It is important to consider possible cognitive and language deficits when using films with patients. Thematic complexity of films varies greatly, thus it is important to match films with the cognitive capabilities of the population being assessed. We have found that, even with highly impaired patients, it is possible to elicit emotion with carefully selected, thematically simple film stimuli.

25.6.4. Slides

The International Affective Picture System (Lang et al., 1988) consists of over 700 colored images of situations that are selected because of their properties

of evoking emotion and being internationally understandable. These pictures have been used in a large number of studies of emotional, cognitive, social, and biobehavioral functioning. Normative ratings of pleasure and arousal for each picture are available, which help in stimuli selection and comparing findings across laboratories. An attempt has been made to find stimuli that fill all quadrants of the pleasure/arousal affective space, including the difficult quadrant comprised of stimuli that are unpleasant, but minimally arousing.

The pictures utilize real-world settings in order to induce the automatic perception of emotion. Although in theory the full array of specific emotions could be represented, there are clear biases (e.g., pictures of contamination and mutilation in the high unpleasant/high arousal quadrant that typically elicit the emotion of disgust).

The IAPS slides are primarily useful for assessing emotional reactivity. Slides that portray emotional facial expressions could also be used to assess that aspect of emotional understanding. Because these pictures are static, cognitively simple, and do not require language processing, they can be very useful when working with impaired patients.

25.6.5. Relived emotions

Recalling memories of emotionally significant events can be a powerful elicitor of emotion. Long-term memories of emotional events may be stored in particularly strong forms due to the interaction of the adrenergic system (which is active during strong emotions) and the amygdala (Cahill, 1996; 1999). Emotional memories may be relatively spared in individuals suffering from retrograde amnesia that affects more neutral or semantic autobiographical memories (Daum et al., 1996; Hamann et al., 1997). A growing body of research suggests that autobiographical memory is mediated by complex networks of frontal, temporal, and occipital areas that differ as a function of type of knowledge, emotional valence, and temporal remoteness (Fink et al., 1996; Conway et al., 2001; Markowitsch, 1999; Peifke et al., 2003).

We use emotional memories of two kinds: personally relevant, autobiographical emotional memories (e.g., recalling one's saddest or happiest moment), and memories of shared historic or group events ('flashbulb' memories such as recalling the events of September 11, 2001). Autobiographical memories can elicit intense emotion, but their idiosyncratic nature leads to differences in the characteristics of memories across individuals. Flashbulb memories provide much better comparability of the memory per se across

individuals but can vary greatly in terms of personal salience and capacity to elicit emotion.

To identify personally relevant autobiographical memories, we use a semi-structured interview format to prompt participants to retrieve memories of specific events that elicited a specific emotion (Ekman et al., 1983). Subsequently, participants are asked to relive those memories as strongly as possible. Emotional responses (self-reported subjective experience, expressive behavior, physiology, language) are assessed during both the retrieval and reliving periods. We consider relived memories to be most useful for assessing emotional reactivity, less so for assessing emotional regulation (it is difficult to both recall/relive a memory and control it at the same time), and least useful for assessing emotional understanding. Because memory is involved, these tasks need to be used judiciously with patients who have memory impairments.

25.6.6. Singing

Among the self-referential emotions, we have focused on embarrassment in our laboratory studies. We use a singing task in which participants unwittingly become an object of attention and evaluation. Participants are seated in front of a television monitor while their expressive behavior is recorded and peripheral physiology monitored continuously. After sitting quietly through a baseline period, they are asked to sing a familiar song—we have been using 'My Girl' by The Temptations, which works well with patients in their 50s and 60s. The instrumental background music is played through headphones, and the lyrics are presented on the television monitor. Upon completion of the song, the experimenter removes the headphones and instructs participants simply to watch the television for the next task. Without warning, they are shown a recording of their just-completed singing performance. In our laboratory, participants are typically alone while watching themselves sing, but it would be possible to have an 'audience' present (Shearn et al., 1990). Singing tasks of this sort are effective elicitors of embarrassment or other signs of self-consciousness (e.g., amusement). Other methods that have been used for this purpose include posing complex facial expressions (Keltner, 1995) or having participants disclose personal, emotional experiences (Beer et al., 2003).

Self-conscious emotions have been associated with regions of the frontal lobes (e.g., medial prefrontal cortex; Takahashi et al., 2004), and are therefore important to assess in individuals who might have frontal lobe damage. Self-conscious emotions serve to regulate social behavior, and when disrupted, can be associated with behavioral disinhibition and violation of social norms (Keltner et al., 1995; Keltner and Buswell, 1997). Corroborative empirical evidence finds that patients with orbitofrontal damage (marked clinically by such behavioral disinhibition) have dysregulated self-conscious emotions (Beer et al., 2003).

The singing task is thematically and instructionally simple and is suitable for use with even quite impaired patients (if patients have trouble reading lyrics, childhood songs like 'Twinkle Twinkle Little Star' can be used). The singing task is less suitable for patients with language and vocal impairments.

25.6.7. Interpersonal interaction

Emotional displays are thought to serve important interpersonal functions, such as facilitating social bonds (e.g., joy during play; Fredrickson, 1998; Panksepp, 2000) and eliciting help from others (e.g., crying as a distress signal; Bowlby, 1969). Exhibiting these displays appropriately, as well as successfully reading and responding to the emotions of others, are critical skills for adaptive emotional functioning. We assess socioemotional functioning in the laboratory by using an interpersonal interaction task that we originally developed to study the interactions of husbands and wives (Levenson and Gottman, 1983). This task allows us to sample naturalistic interpersonal interaction between patients and their spouses, partners, or caregivers. It provides a 'real world' assessment of emotional reactivity (generating emotional responses during the interaction), emotional regulation (modulating emotions appropriately for the situation), and emotional understanding (recognizing and responding to the emotions of the other person).

In this task, the patient and interaction partner sit in chairs facing each other and engage in 15-minute conversations preceded by a 5-minute silent resting period; during this 20-minute task behavior is videotaped and physiology is monitored continuously from both patient and partner. We have found the most powerful elicitor of emotion is having the dyad discuss an area of conflict in their relationship. We also use neutral topics (e.g., discussing the events of the day), positive topics (e.g., discussing things they enjoy doing together), or disease-specific topics (e.g., discussing the way the illness has changed their relationship). Before each conversation, a facilitator helps the dyad decide on the topic for discussion.

Interpersonal interactions provide an additional way of assessing emotional understanding. After the conclusion of each conversation, we have participants view the video recording and use a rating dial to report continuously on the valence (negative–neutral–positive) of their own emotions during the interaction

Table 25.1

Laboratory tests of emotional processing

	Emotion processes	Emotion types	Emotion response systems	Advantages and disadvantages	For bedside use
Acoustic Startle Reflex	Reactivity Regulation (instructed and spontaneous)	Negative Positive and Self-referential in secondary reaction	Subjective Behavioral Physiological	Requires little cognitive processing Produces a general defensive response rather than specific emotions	Acoustic startle presented via recording and headphones
Startle Eye-blink Modulation	Reactivity	Negative Positive	Behavioral	Requires little cognitive processing Unobtrusive and continuous	Acoustic startle presented via recording and headphones; simple electromyographic device
Films	Reactivity Regulation (instructed) Understanding (identify or track emotions of target)	Negative (anger difficult) Positive Self-referential	Subjective Behavioral Physiological	Require cognitive processing Difficult to elicit anger	Films presented via laptop or portable video device
Slides	Reactivity Regulation (instructed)	Negative (anger difficult) Positive	Subjective Behavioral Physiological	Minimal cognitive and language demands Biased toward eliciting disgust, amusement, sexual arousal	Slides presented via laptop or portable video device
Relived emotions	Reactivity	Negative Positive Self-referential	Subjective Behavioral Physiological Language	Makes high demands on memory Idiosyncratic stimuli—not standardized	No additional instrumentation needed
Singing	Reactivity	Self-referential	Subjective Behavioral Physiological	Task needs to be simplified for very impaired patients	Music presented via tape or laptop; camcorder for playback of singing
Dyadic Interaction	Reactivity Regulation (instructed and spontaneous) Understanding	Negative Positive Self-referential	Subjective Behavioral Physiological Language	Produces highly naturalistic sample of emotional functioning Responses influenced by both members of dyad	No additional instrumentation needed

(Gottman and Levenson, 1985). This can be followed by a second viewing in which each participant rates his or her partner's emotional state. Comparing the two sets of ratings gives an objective indicator of the ability of partners to understand each other's emotions.

The neural correlates of emotional understanding, particularly in dynamic or social contexts, have not been extensively studied. Using more static stimuli in less interpersonal contexts, both lesion and imaging studies implicate a wide range of brain areas associated with the recognition of negative emotions, including the amygdala, thalamus, insula, anterior cingulate, right somatosensory and parietal cortices, anterior temporal cortex, and frontal and prefrontal areas, especially in the orbitofrontal and medial areas (e.g., Reiman et al., 1997; Sprengelmeyer et al., 1999; Calder et al., 2000; Adolphs et al., 2000; 2002; Wicker et al., 2003). Difficulties comprehending emotional prosody have been associated with right-hemisphere lesions involving basal ganglia and temporoparietal cortex and atrophy in frontal and diencephalic areas in acute stroke patients (Starkstein et al., 1994).

Although static emotional stimuli are quite convenient, interpersonal interaction provides a powerful and natural way to study most aspects of emotional functioning. Even with quite impaired patients, interpersonal interaction can provide a vivid snapshot of emotional strengths and deficits, including important nuances (e.g., mutual gaze patterns, listening behaviors) that may not be revealed using other methods.

25.6.8. Control tasks

When working with frontal lobe patients, we typically have access to a fairly complete clinical examination and neuropsychological workup. This information is extremely helpful in identifying problems with attention, memory, language, etc., that could influence our assessment of emotional functioning. Furthermore, additional simple testing of particular systems relevant to emotional functioning is helpful in interpreting results. For this purpose, we typically assess: (a) understanding of emotion terms—a test in which terms such as 'anger' and 'fear' are matched with a list of definitions; (b) knowledge of the content of the emotion-eliciting stimuli—to ensure that the stimuli we present to the patient are processed appropriately; (c) autonomic functioning—we use an isometric handgrip task and sometimes a valsalva maneuver to ensure that autonomic responding is intact; and (d) facial muscle movement—a simple test of the ability to make simple facial muscle movements (e.g., lowering the eyebrows) and emotional facial expressions (e.g., happy) is helpful to identify any abnormalities.

25.7. Laboratory and bedside testing

In Table 25.1 we summarize the various laboratory tests of emotional processing in terms of the emotion processes, types, and response systems they sample; their advantages and disadvantages; and their suitability for use at the bedside.

Despite the fact that much of our laboratory testing of emotional functioning makes use of considerable computing, physiological monitoring, and audiovisual resources, most of the tests can be simplified for bedside use. Audio and video stimulus presentation can be accomplished via laptop computer; self-report responses can be entered in a laptop or recorded on paper; expressive behavior can be recorded via small camcorders or 'coded' in real time; and peripheral physiology can be monitored manually, via portable devices, or using analog-to-digital interfaces that connect to the laptop.

25.8. Conclusion

In this chapter we have provided an overview of a more differentiated view of emotional functioning in neurological patients than has been typical in the clinical and research literatures. It is our belief that comprehensive testing of emotional functioning should consider key emotion processes (reactivity, regulation, understanding), types (negative, positive, self-referential), and response systems (self-reported experience, expressive behavior, peripheral physiology, language). We believe that this kind of assessment will not only help inform and improve diagnosis and treatment of those neurological disorders that exact a toll on emotional functioning, but also increase our understanding of the neural substrates of emotion.

We have also described a number of tests that can be used in the laboratory to obtain this kind of differentiated, comprehensive assessment of emotional functioning. It is our hope that as data accumulate using these methods on normal and neurological populations, those tests that prove most useful and that provide unique diagnostic information can be migrated relatively rapidly for use at the bedside.

References

Adolphs R, Damasio H, Tranel D (2002). Neural systems for recognition of emotional prosody: A 3-D lesion study. Emotion 2: 23–51.

Adolphs R, Damasio H, Tranel D, et al. (2000). A role for somatosensory cortices in the visual recognition of emotion as revealed by three-dimensional lesion mapping. J Neurosci 20: 2683–2690.

Beer JS, Heerey EA, Keltner D, et al. (2003). The regulatory function of self-conscious emotion: Insights from patients with orbitofrontal damage. J Pers Soc Psychol 85: 594–604.

Bradley MM, Vrana SR (1993). The startle probe in the study of emotion and emotional disorders. In: N Birbaumer, A Ohman (Eds.), The Structure of Emotion. Hogrete & Huber, Seattle, WA, pp. 270–287.

Bowers D, Blonder L, Heilman K (1992). The Florida Affect Battery. Center for Neuropsychological Studies, Cognitive Neuroscience Laboratory, Gainesville, FL.

Bowlby J (1969). Disruption of affectional bonds and its effects on behavior. Can Ment Health 59: 12.

Cahill L (1996). Neurobiology of memory for emotional events: Converging evidence from infra-human and human studies. Cold Spring Harb Symp Quant Biol 61: 259–264.

Cahill L (1999). A neurobiological perspective on emotionally influenced, long-term memory. Semin Clin Neuropsychiatry 4: 266–273.

Calder AJ, Keane J, Manes F, Antoun N, Young AW (2000). Impaired recognition and experience of disgust following brain injury. Nat Neurosci 3: 1077–1078.

Conway MA, Pleydell-Pearce CW, Whitecross SE (2001). The neuroanatomy of autobiographical memory: A slow cortical potential study of autobiographical memory retrieval. J Mem Lang 45: 493–524.

Chu C-C, Tranel D, Damasio AR, et al. (1997). The autonomic-related cortex: Pathology in Alzheimer's disease. Cereb Cortex 7: 86–95.

Damasio AR, Tranel D, Damasio H (1990). Individuals with sociopathic behavior caused by frontal damage fail to respond autonomically to social stimuli. Behav Brain Res 41:81–94.

Daum I, Flor H, Brodbeck S, et al. (1996). Autobiographical memory for emotional events in amnesia. Behav Neurol 9:57–67.

Ekman P, Friesen WV (1978). Facial Action Coding System. Palo Alto, CA, Consulting Psychologists Press.

Ekman P, Friesen WV, Simons RC (1985). Is the startle reaction an emotion? J Pers Soc Psychol 49: 1416– 1426.

Ekman P, Levenson RW, Friesen WV (1983). Autonomic nervous system activity distinguishes among emotions. Science 221:1208–1210.

Fink GR, Markowitsch HJ, Reinkemeier M, et al. (1996). Cerebral representation of one's own past: Neural networks involved in autobiographical memory. J Neurosci 16: 4275–4282.

Fredrickson BL (1998). What good are positive emotions? Rev Gen Psychol 2:300–319.

Fredrickson BL, Levenson RW (1998). Positive emotions speed recovery from the cardiovascular sequelae of negative emotions. Cogn Emott 12: 191–220.

Gottman JM (1989). The specific affect coding system (SPAFF). Unpublished research manual, University of Washington.

Gottman JM, Levenson RW (1985). A valid procedure for obtaining self-report of affect in marital interaction. J Consult Clin Psychol 53:151–160.

Gross JJ (1998). The emerging field of emotion regulation: An integrative review. Rev Gen Psychol 2: 271–299.

Gross JJ, Levenson RW (1993). Emotional suppression: Physiology, self-report, and expressive behavior. J Pers Soc Psychol 64:970–986.

Gross JJ, Levenson RW (1995). Emotion elicitation using films. Cogn Emot 9: 87–108.

Hamann SB, Cahill L, McGaugh JL, et al. (1997). Intact enhancement of declarative memory for emotional material in amnesia. Learn Mem 4: 301–309.

Hubert W, de Jong-Meyer R (1990). Psychophysiological response patterns to positive and negative film stimuli. Biol Psychol 31: 73–93.

Isen AM (1999). Positive Affect. New York, NY, John Wiley & Sons Ltd.

Keltner D (1995). Signs of appeasement: Evidence for the distinct displays of embarrassment, amusement, and shame. J Pers Soc Psychol 68: 441–454.

Keltner D, Buswell BN (1997). Embarrassment: Its distinct form and appeasement functions. Psychol Bull 122: 250–270.

Keltner D, Moffitt TE, Stouthamer-Loeber M (1995). Facial expressions of emotion and pscyhopathology in adolescent boys. J Abnorm Psychol 104: 644–652.

Lang PJ (1994). The motivational organization of emotion: Affect-reflex connections. In: SHM van Goozen, NE van de Poll, JA Seargeant (Eds.), Emotions: Essays on Emotion Theory. Lawrence Erlbaum Associates, Hillsdale, NJ, pp. 61–93.

Lang PJ, Bradley MM, Cuthbert BN (1990). Emotion, attention, and the startle reflex. Psychol Rev 97: 377–395.

Lang PJ, Greenwald MK, Bradley MM (1988). The International Affective Picture System (IAPS) standardization procedure and initial group results for affective judgments (Technical reports 1A-1D). Center for the Study of Emotion and Attention, University of Florida.

Larson CL, Sutton SK, Davidson RJ (1998). Affective style, frontal EEG asymmetry, and the time-course of the emotion-modulated startle response. Poster presented at the 38th annual meeting of the Society for Psychophysiological Research, Denver, Colorado.

Lazarus R, Speisman J, Mordkoff A, Davidson L (1962). A laboratory study of psychological stress produced by a motion picture film. Psychol Monogr 76 (whole number 553).

Levenson RW (1988). Emotion and the autonomic nervous system: A prospectus for research on autonomic specificity. In: HL Wagner (Ed.), Social Psychophysiology and Emotion: Theory and Clinical Applications. John Wiley & Sons, Chichester, UK, pp. 17–42.

Levenson RW (1994). Human emotion: A functional view. In: P Ekman, RJ Davidson (Eds.), The Nature of Emotion: Fundamental Questions. Oxford, New York, pp. 123–126.

Levenson RW (2003). Autonomic specificity and emotion. In: RJ Davidson, KR Scherer, HH Goldsmith (Eds.), Handbook of Affective Sciences. Oxford University Press, New York, pp. 212–224.

Levenson RW, Gottman JM (1983). Marital interaction: Physiological linkage and affective exchange. J Pers Soc Psychol 45: 587–597.

Levenson RW, Ruef AM (1992). Empathy: A physiological substrate. J Pers Soc Psychol 63: 234–246.

Markowitsch HJ, Calabrese P, Neufeld H, Gehlen W, Durwen HF (1999). Retrograde amnesia for world knowledge and preserved memory for autobiographic events. A case report. Cortex 35: 243–252.

Mauss IB, Levenson RW, McCarter L, et al. (2005). The tie that binds? Coherence among emotion experience, behavior, and physiology. Emotion 5: 175–190.

Mergenthaler E (1985). Textbank Systems: Computer Science Applied in the Field of Psychoanalysis. Springer, Heidelberg.

Panksepp J (2000). The riddle of laughter: Neural and psychoevolutionary underpinnings of joy. Curr Dir Psychol Sci 9: 183–186.

Piefke M, Weiss PH, Zilles K, Markowitsch HJ, Fink GR (2003). Differential remoteness and emotional tone modulate the neural correlates of autobiographical memory. Brain 126: 650–668.

Reiman EM, Lane RD, Ahern GL, Schwartz GE, Davidson RJ, Friston KJ, et al. (1997). Neuroanatomical correlates of externally and internally generated emotion. Am J Psychiatry 154: 918–925.

Roberts NA, Beer JS, Werner KH, et al. (2004). The impact of orbital prefrontal damage on emotional activation to unanticipated and anticipated acoustic startle stimuli. Cogn Affect Behav Neurosci 4: 307–316.

Shearn D, Bergman E, Hill K, Abel A, Hinds L (1990). Facial coloration and temperature responses in blushing. Psychophysiology 27: 687–693.

Sokolov EN (1963). Higher nervous functions: The orienting reflex. Annu Rev Physiol 25: 545–580.

Soto JA, Levenson RW, Ebling R (2005). Cultures of moderation and expression: Emotional experience, behavior, and physiology in Chinese Americans and Mexican Americans. Emotion 5: 154–165.

Starkstein SE, Federoff JP, Price TR, et al. (1994). Neuropsychological and neuroradiologic correlates of emotional prosody comprehension. Neurology 44: 515–522.

Sturm VE, Rosen HJ, Allison S, et al. (2006). Self-conscious emotion deficits in frontotemporal lobar degeneration. Brain 129: 2508–2516.

Sprengelmeyer R, Young AW, Schroeder U, et al. (1999). Knowing no fear. Proc R Soc Lond B Biol Sci 266: 2451–2456.

Takahashi H, Yahata N, Koeda M, et al. (2004). Brain activation associated with evaluative processes of guilt and embarrassment: An fMRI study. Neuroimage 23: 967–974.

Vrana SR, Spence EL, Lang PJ (1988). The startle probe response: A new measure of emotion? J Abnorm Psychol 97: 487–491.

Wicker B, Keysers C, Plailly J, et al. (2003). Both of us disgusted in my insula: The common basis of seeing and feeling disgust. Neuron 40: 655–664.

Young A, Perrett D, Calder A, et al. (2002). Facial Expressions of Emotion: Stimuli and Tests. Thames Valley Test Company, Bury St. Edmunds, UK.

Chapter 26

Neuropsychological characterization of mild cognitive impairment

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26.1. Introduction

With the increasing of the population of older adults, there is a growing interest in improving quality of life in old age and in early detection and prevention of cognitive decline. One important aspect of this endeavor is to identify individuals at an earlier point in the cognitive decline such that therapeutic interventions can be aimed at this juncture. Mild cognitive impairment (MCI) has been proposed as a condition of intermediate symptomology between the cognitive changes of aging and fully developed symptoms of dementia such as those seen in Alzheimer's disease (AD). The rationale for the study of MCI is derived from the assumption that the sooner one intervenes in a degenerative process, the more likely the damage done to the central nervous system can be prevented. Hence the construct has been developed to represent a transitional stage between the cognitive changes of aging and very early dementia.

26.2. History

The concept of MCI has evolved considerably over the years. The first attempt to characterize cognitive changes at the normal tail-end of the continuum dates back to 1962, where VA Kral used the term *benign senescent forgetfulness* to describe very early memory concerns with aging (Kral, 1962). This was followed by a National Institute of Mental Health workgroup in 1986 that proposed the term *age-associated memory impairment (AAMI)* to refer to memory changes that were felt to be variant of normal aging (Crook et al., 1986). Shortcomings of AAMI included restriction of

impairment to memory domain only and comparison of memory function in older adults to performance of young adults. As such, AAMI was unable to delineate individuals at risk of developing pathological conditions from those undergoing the processes of normal aging. The international psychogeriatric association coined the term *age associated cognitive decline (AACD)* in an effort to bypass many of the shortcomings recognized in AAMI (Levy, 1994). The operational criteria for AACD referenced a variety of cognitive domains presumed to decline in normal aging and included age- and education-adjusted normative values. Alternatively, the Canadian Study of Health and Aging coined the term *cognitive impairment–no dementia (CIND)* to identify individuals with impaired cognitive function but not of sufficient severity to constitute dementia (Graham et al., 1997). In many respects these 'in-between' persons resemble MCI subjects but the CIND label actually includes a broader subset of the population. The construct of CIND encompasses individuals with lifelong cognitive impairment, static encephalopathy, and learning disability. Recently, some investigators have defined subsets of persons with CIND who more closely resemble MCI subjects (Fisk et al., 2003).

The term MCI was initially used in the late 1980s by Reisberg and colleagues to describe individuals with a Global Deterioration Scale (GDS) of 3 (Reisberg et al., 1982; 1988; Flicker et al., 1991). Another classification has used the Clinical Dementia Rating Scale (CDR) to identify individuals with CDR 0.5 stage of 'questionable dementia.' (Morris, 1993; Morris et al., 2001) While both GDS and CDR are useful scales for classification of individuals along the continuum of severity of cognitive impairment, they do not necessarily correspond to

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