CHAPTER

16

c00017 # The Study of Emotion in Neuroeconomics

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OUTLINE

s0010 ## INTRODUCTION

p0010 Neuroeconomic models of decision-making have emphasized the assessment of value as a critical factor in driving choice behavior. Although the term *value* is used extensively in economic research, its precise definition can be somewhat elusive due to range of factors that might influence its determination (Bernoulli, 1954). Nevertheless, there is general agreement that the role of value is to provide a metric for the decision-maker in weighing various options for action or choice. In the disciplines of psychology and neuroscience, another term that has been used to describe the appraisal or evaluation of events in the service of motivating action is *emotion* (Fridja, 1986; LeDoux, 1987; Scherer, 2005). Like value, emotion is a term whose precise definition can be elusive. Broadly speaking, emotion can be thought to be a "relevance detector" that lets us know what is important or significant (see, for example, Fridja, 1986). Under this broad category, however, it is widely recognized that the term *emotion*, as it is used in everyday language, represents a range of factors and processes that can be further delineated and assessed. Although a component of what might be considered emotion or affect overlaps with the concept of value, there are number of other emotion variables that are independent of value, but may also influence decision-making.

By linking economic decision-making to brain function, the emerging field of neuroeconomics has p0020

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highlighted the overlap in the neural systems that mediate choice and other behaviors, including emotion. Like cognitive neuroscience before, the clean division between cognition (or reason) and emotion in economic decision-making is blurred when attempting to understand the neural circuitry mediating these classes of behaviors (Phelps, 2006). Although emotion was considered an important variable in economic decision-making prior to neuroeconomics (Mellers, 2000; Kahneman, 2003; Lowenstein and Lerner, 2003), the recent growth in this field has highlighted a role for emotion in economic choices (see, for example, Bechara *et al*., 1997; Cohen, 2005; Shiv *et al*., 2005). However, this growing interest in the role of emotion in decision-making has rarely been coupled with the detailed investigation of the range of components, factors, and measures that have characterized the psychological study of emotion and affect.

p0030 The goal of this chapter is to introduce neuroeconomic researchers to some of the definitions, manipulations, and assessments of emotion that have been used in psychological and neuroscience research. To date, most neuroeconomic studies have depicted emotion as a single, unified variable that may drive choice, often in contrast to a reasoned analysis of the options and their relative values (see, for example, Cohen, 2005). This dual-system approach, although intuitively appealing, fails to consider the complexity of emotion or to capture the range of possible roles for emotion and affect variables in decision-making. Adopting a more nuanced understanding of emotion will help clarify its impact on economic decision-making and provide a basis for further understanding the complex interactions between emotion, value, and choice.

p0040 In affective science, there has been long-standing and considerable theoretical debate about the underlying structure of emotion and the parsing of emotional experience (for example, Barrett, 2006; Fridja, 2007a). These debates will not be reviewed here; rather, the focus will be on some of the more practical definitions, manipulations, and assessments that have advanced psychological research on emotion and affect, particularly as it relates to cognition and social behavior. When possible, how these different factors have been (or could be) used to advance economic and neuroeconomic research on decision-making will be highlighted.

s0020 DEFINING COMPONENTS OF EMOTION AND AFFECT

p0050 One common approach to defining emotion has been to differentiate components of emotion and affect. Although there is debate about the properties of specific components, there is also significant overlap among component process theories of emotion (Fridja, 2007a). The framework presented below is largely based on the proposal of Scherer and colleagues (Scherer, 2000, 2005), with some modifications due to my own interpretation and emphasis, but many of the basic concepts have been suggested by other scholars as well (such as James, 1884; Cannon, 1929; Fridja; 1986, 2007b; LeDoux, 1987).

Emotion s0030

Although the term *emotion* is commonly used to capture all affective experience, in component process theories of emotion and affect the term is proposed to reflect the discrete response to an external or internal event that entails a range of synchronized features, including subjective experience, expression, bodily response, and action tendencies. An additional important component of emotion is the evaluation and appraisal of the event. The characterization of emotion as a discrete, time-limited response to an internal or external event differentiates it from a range of other affective experiences. For an emotion to occur, it is not critical that all of the features are present, but rather that some subset are expressed in a relatively synchronized, temporally discrete manner. Each of these features is further characterized below. p0060

Subjective Experience: Emotion vs Feeling s0040

One of the primary sources of confusion in emotion research is the relation between emotion and feeling. The subjective experience of emotion, called *feeling*, is just one of the features that affective scientists consider a component of emotion. To laypersons reflecting on their experience, feelings are the consciously accessible and therefore most prominent characteristic of emotion, which may help explain why the terms emotion and feeling are often used interchangeably. In William James' seminal paper "What is Emotion"(1884), he differentiates feeling afraid from the perception and bodily response to seeing a bear, but early emotion theorists, including James, emphasized feelings as a critical characteristic of emotion. However, most emotion researchers today acknowledge that there are several responses that portray an emotion that do not depend on feeling (LeDoux, 1996). For research in non-human animals this distinction is critical, since subjective experience is not accessible in other species, but other types of emotional responses, such as physiological changes, are easily assessed and have characteristic patterns across species. In humans p0070

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there is evidence the subjective experience of emotion does not always correspond with other expressions of emotion (Öhman *et al*., 2000; Funayama *et al*., 2001; Winkielman *et al*., 2005), providing support for the suggestion that the subjective experience of emotion is neither critical nor necessary to determine that an emotion has occurred. Nevertheless a conscious, subjective experience, or feeling, is a common characteristic of emotion, as well as other affective states, such as mood (see below).

s0050 *Expression*

p0080 Both expression and bodily response might be considered reactions to emotion-eliciting events. They are distinguished here because of their potentially different roles in emotion. *Expression* refers here to motor responses in the face, voice or body that portray the emotion to others in a social environment. The expression of emotion has been most often been studied in the characteristic motor response of the face when a person is experiencing an emotion. Darwin (1872/2002) suggested that the patterned facial expressions of emotion evolved for two functions, the first being as a means of social communication to allow conspecifics to both benefit from the emotional reactions of others, such as fear to a threatening stimulus or disgust to a noxious stimulus, and to determine the intent of others, such as smiling in appeasement or anger when threatening. The second proposed function of facial expressions, which has not been widely studied, is to alter the perceptual experience in adaptive ways by changing the facial configuration, such as widening the eyes to obtain more visual information in fear, or restricting the nasal passages to limit olfactory sensation in disgust.

p0090 The characteristic motor response for some basic facial expressions (see the section on Basic emotions, below) has been well characterized, and is thought to be universal and similar across cultures (Ekman and Friesen, 1971). There is substantial research into both the development of facial expression perception (e.g., Baenninger, 1994; Widen and Russell, 2003; Thomas *et al*., 2007) and its underlying neural circuitry of facial expression perception (Adolphs, 2002). In contrast, relatively less is known concerning the vocal (Johnstone and Scherer, 2000) and bodily expression of emotion, although there is some evidence that the similar neural circuitry underlies the perception of emotional expressions across modalities (de Gelder, 2006).

s0060 *Bodily Response*

p0100 One of the unique characteristics of emotion is the patterned behavioral, hormonal, and autonomic responses that follow the perception of an emotion-eliciting event. Under this heading are also included neuromodulatory changes that characterize the impact of arousal and stress on the brain (LeDoux, 1996). In contrast to emotional expressions, in which a primary function might be the communication of emotion, bodily reactions are thought to be adaptive in preparing the organism to respond. A classic example is the "flight or fight" response, in which in the face of threat the sympathetic branch of the autonomic nervous system prepares the organism for quick action by changing the physiological state, such as increasing heart rate, blood pressure, respiration, and sweating (Cannon, 1929). In addition to hormonal, autonomic, and neuromodulatory responses there are also behavioral reactions – such as freezing, altering the amplitude of the startle reflex, or automatic withdrawal from a painful stimulus – that characterize the bodily response to emotion.

The characteristic patterns of expression and p0110 bodily response of emotion provide a powerful means to assess emotional reactions using psychophysiological techniques that are non-intrusive and do not depend on subjective experience or verbal report. In addition, the similarities in many of these patterns across species provide some assurance that studies of emotion in non-humans are capturing emotion reactions and qualities that are equally relevant to human experience.

Action Tendencies s0070

In contrast to bodily responses, in which any behav- p0120 ioral motor actions that occur may be best characterized as automatic, reflexive reactions, emotion also elicits a tendency towards action that does not have a predictable motor pattern and is expressed as instrumental responses. These action tendencies motivate the organism towards a particular class of actions, such as approaching or withdrawing, but the actual action taken is modified by current goals and the situation. For instance, the tendency to move away from and avoid a stimulus that predicts potential threat is an instrumental response to an emotion-eliciting event. Exactly how the threat is avoided depends on the situation and options available. Similarly, there is a tendency to approach a stimulus that is rewarding, which can be expressed by a range of instrumental responses. The actual behavioral response, or action, is not determined by the emotion, but rather the emotional response motivates a class of potential actions, or tendencies.

Although action tendencies are assessed with p0130 instrumental responses that are constrained by the

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current goals and circumstances, and in this way they differ from automatic reactions, they are not necessarily under conscious control. For example, action tendencies can be expressed in a change in reaction time to emotion-eliciting events (e.g., Pratto and John, 1991), alterations in specific, motivationally congruent motor responses (e.g., Chen and Bargh, 1999); and the frequency of an instrumental response (Rescorla and Solomon, 1967), as well as choosing among options.

s0080 *Evaluation and Appraisal*

p0140 The primary function of emotion is to highlight the significance or importance of events so that these events receive priority in further processing. For an emotion to occur, there needs to be an assessment of the relevance of the internal or external emotion-eliciting event to the organism. Although there is some debate among affective scientists about the importance of different aspects of this assessment (Lazarus, 1984; Zajonc, 1984), there is general agreement that this assessment is a process with more than one relevant factor (Fridja, 2007b; LeDoux, 2007; Scherer, 2005). For the purposes of description two of these factors, evaluation and appraisal, are differentiated here, although these terms are often used interchangeably.

p0150 The *evaluation* of the relevance or significance of event can occur rapidly, without conscious awareness or cognitive interpretation (Zajonc, 1984). There is abundant psychological and neuroscience evidence indicating that the emotional significance of an event and some emotional reactions do not depend on being consciously aware of the event (LeDoux, 1996; Bargh and Chartrand, 1999). A well-known example of this fast, non-conscious evaluation of emotional events is the subcortical pathway for detecting the presence of auditory tones that have been paired with aversive shock in a fear conditioning paradigm. In a classic study, Romanski and LeDoux (1992) showed that rats demonstrate fear responses to a tone paired with shock, even when the auditory cortex is lesioned. These conditioned fear responses depend on subcortical pathways in which the auditory thalamus projects directly to amygdala, which mediates the expression of conditioned fear. The evidence of a fear response without sensory cortical processing is a strong demonstration that the evaluation of emotional significance can be rapid and independent of awareness. However, the presence of a subcortical pathway for eliciting emotion should not be taken to mean that cortical processing does not mediate most emotional responses, including those that are unconscious. There are many examples of emotional responses elicited by events that are not available to awareness, but could not be detected without cortical processing for perception and evaluation (e.g., Bargh and Chartrand, 1999; Whalen *et al.*, 2004).

Although the emotional evaluation of an event can occur rapidly and without awareness, it is more often the case that we are aware of the emotional significance of an event. This awareness and the cognitive interpretation of the meaning of the event can initiate and alter an emotional response (Lazarus, 1984). The conscious assessment, cognitive monitoring, and interpretation of the significance of the event is referred to as *appraisal*. The appraisal of an event can occur rapidly, or can unfold as the circumstances surrounding the event provide additional cues to its significance. The importance of the appraisal process has been most often cited in relation to its impact on the subjective experience of emotion. In a classic study, Schacter and Singer (1962) evoked physiological changes consistent with emotion by administering epinephrine, but only informed a subset of participants that the bodily changes may be related to the drug. They then placed all the participants in the social circumstances that might evoke happiness or anger. The participants who were unaware of the cause of their bodily changes were more likely to report the subjective experience of euphoria or anger, and behave in a manner consistent with these emotions. In this case, the appraisal of the situation resulted in a change in the subjective experience and expression of emotion. These results, and others, suggest that the appraisal of an event may be closely tied to the subjective experience of emotion, but this does not imply that appraisal is linked solely to subjective experience. The appraisal of an event elicits and modifies all the features of emotion. p0160

Mood s0090

Emotions are characterized by synchronized, discrete responses to an event that may be high in intensity. In contrast, *mood* is a diffuse affect state characterized primarily by subjective feelings that are relatively enduring and of generally low intensity. Although a mood can be elicited by the appraisal of an event, it can also emerge with no apparent cause. The predominant feature of mood is the subjective experience, but moods can influence behavior in a number of ways that are generally less event-focused than emotion, attitudes, or preferences. p0170

Attitude and Preference s0100

Many affective scientists differentiate attitude and preference (e.g., Scherer, 2005), but here they have p0180

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been grouped because they share many of the same properties. Like emotion, attitude and preference require the evaluation or appraisal of an event. Unlike emotion, attitudes and preferences are only elicited by external events such as another person, a group of people, an object, or a situation. The primary feature of attitudes and preferences is the affective evaluation of the external event. With *preferences* this evaluation is often described in terms of intrinsic liking or disliking, whereas with *attitudes* this evaluation is usually described in terms of valence of the affective response (i.e. good–bad). A key component of attitudes and preferences is that they result in a relatively enduring affective state linked to the properties or interpretation of the object or event. This affective state, while relatively enduring and consistent, can be modified somewhat by the situation, such as a change in preference for a particular food when sated. The affective state elicited by attitudes and preferences is generally described as low or medium intensity, and the primary behavioral impact is a tendency to approach or avoid the eliciting stimulus. Although attitudes and preferences both have subjective affective states and motivational components, social psychologists generally include a cognitive component (i.e. beliefs about the object) as a third important variable of attitudes (Breckler, 1984).

p0190 The notion of *value* in economics is most similar to the affective variable *preference*. Because of this, it is important carefully to consider the differences and similarities between preference and emotion in our efforts to understand their impact on economic decisions. As mentioned above, both preference and emotion are elicited by the evaluation and appraisal of external events, although emotions are also elicited by internal events. Preferences and emotions share two features; a subjective affective state and an action tendency. With preference, the subjective affective state is described as intrinsic liking or disliking. For emotion, it is described as feeling. Both preferences and emotions elicit action tendencies to approach or avoid that can be expressed with a range of behavioral responses, or not expressed at all.

p0200 In contrast to preference, emotion has two additional features: expression and bodily response. Emotion is also characterized as a synchronized, discrete response. Because of the time-limited nature of the response, emotion can be of higher intensity than might be expected with preference. With high-intensity emotions there may be a more immediate impact on behavior, or a faster disruption of ongoing behavior, but not all emotional reactions will have this quality. These different features suggest some of ways that the line between emotion and preference can become blurred. Although preferences are not described as eliciting expressions or bodily responses, it is certainly possible to like or dislike an object or event so much that this is expressed in the face or body. In addition, even though emotion is described as a discrete response, whereas a preference is more enduring, the same object can elicit both a consistent and discrete, synchronized response to its presentation, and a longer-lasting evaluation of liking or disliking. In short, the same stimulus can elicit both preference and emotion. The difference between the two may simply be a matter of degree. Given this, disentangling their impact in relation to the assessment of value and decision-making may, at times, be difficult.

Other Affect Phenomena s0110

The final two affect variables proposed by Scherer and colleagues (2000, 2005) are related to affective traits and situational style, and will only briefly be summarized here. *Affect dispositions* are relatively enduring traits that vary among individuals. For example, some individuals may be described as generally more happy, anxious, or angry than others. This persistent tendency over a range of situations and episodes to react in a relatively consistent manner suggests an affect disposition. In economic research, individual variability in factors such as sensitivity to risk across a range of situations would be similar to an affect disposition. Affect dispositions are also related to clinical disorders that have an affective component. *Interpersonal stance* is an affective style that colors interpersonal exchange in a social situation, and may be shaped by affect dispositions, attitudes and preferences, and strategic intentions. For example, a person with a tendency towards anger, when encountering someone she dislikes, may adopt a hostile approach to the social or economic exchange that may influence her actions and choices (see Scherer, 2005 for a review). p0210

CATEGORIES OF EMOTION AND AFFECTIVE EXPERIENCE s0120

When describing an affective experience, such as emotion, mood, or attitude, we are referring not only to the processes engaged but also to the quality of the state. For instance, it is rare that an emotion is mentioned without also labeling it using terms such as anger, happiness, guilt, etc. Below, two commons means of characterizing the quality of affective experience and that have been used in psychological and p0220 neuroscience research are described. The approaches mentioned are used most frequently in affective research, but there are other proposed methods as well (see, for example, Scherer, 2005). It is important to note that these common categorization schemes may not always capture the range of affective experience that might be relevant to research on emotion and decision-making. In general, the method of characterizing the affective state in studies of emotion is driven by the constraints of the experiment and means of assessment, as well as the specific question being addressed.

s0130 Basic Emotions

p0230 In his seminal work *The Expression of Emotion in Man and Animal*, Charles Darwin (1872/2002) proposed that there is a limited number of basic, universal human emotions. He derived this idea in part from colleagues who had studied different cultures around the world. When Darwin asked his colleagues about the emotional lives of individuals from other cultures, they reported similar emotional facial expressions. Darwin suggested that this universality of emotional expression suggests a common emotional experience.

p0240 More recently, Paul Ekman and his colleagues studied the facial expression of emotion and suggested that there are six basic emotional expressions: happiness, sadness, fear, anger, disgust, and surprise (Ekman and Friesen, 1971). Each of these expressions is characterized by a unique subset of facial muscle movements. The ability to convey these emotional expressions appears to be innate. Infants will display these facial expressions, as will individuals blind since birth and thus have not had the opportunity to view and mirror these expressions. Ekman has verified that these same facial expressions are observed across cultures, although the frequency of their expression is modified by cultural norms (Ekman, 1994). Studies examining the vocal expression of the emotion also provide some evidence for basic emotions (Johnstone and Scherer, 2000).

p0250 To the extent that facial expression indicates an emotional state, this research suggests that there may be basic, human emotions. Whether or not these patterned facial expressions are indicative of unique states has been a matter of debate (Barrett, 2006). Despite years of significant effort, there is relatively little evidence to suggest that these basic emotions are reflected in corresponding, unique patterns of autonomic responding (Cacioppo *et al*., 2000a; Mauss *et al*., 2005). Studies examining the neural circuitry mediating the perception of the basic emotions provide support for a unique neural circuitry for some basic emotional expressions, but there is also significant overlap between the neural patterns mediating the perception of different facial expressions (Calder and Young, 2005). In research on emotion, these basic facial expressions have proved useful in both assessing emotion perception and evoking corresponding emotional responses in others. However, it is important to acknowledge that these six basic emotions do not capture the range of human emotional experience. There are several more complex emotions, such as guilt and love, which are less clearly linked to specific facial or vocal displays.

Dimensions of Emotion s0140

Another approach that has been used in the scientific investigation of emotion is to classify the range of emotion and affect states according to a few specific dimensions. The primary dimensional approach used in research on emotion and affect is captured by the *Circumplex* model. This model proposes that a number of emotional reactions and affective states can be characterized by two dimensions: arousal (activation–deactivation) and valence (pleasant–unpleasant) (Russell, 1980; Russell and Barrett, 1999). *Arousal* refers to the strength or intensity of the physiological response (or subjective judgment of physiological reaction) to a stimulus and the mobilization of energy. *Valence* reflects the degree to which the experience is pleasant (positive) or unpleasant (negative). Using these dimensions, the Circumplex model creates a framework for capturing a range of emotion and affect states. For example, sad, fearful, excited, and nervous are considered to be discrete emotional states. The Circumplex model suggests that these discrete states could be understood as varying along the dimensions of arousal and valence. Sad and fearful are both unpleasant, but sad is not as arousing or activating as fearful. Excited and nervous are both arousing states, but excited is relatively positive and nervous is relatively negative. p0260

One advantage of this approach is that, by limiting the number of response categories to a few dimensions, the subjective judgment of the emotional state may be less influenced by the constraints of the question. In addition, the dimension of arousal is captured by physiological and neuromodulatory patterns that have been well characterized and can be assessed across species (Cannon, 1929; LeDoux, 1996). There are also some physiological indicators that capture valence (Lang *et al*., 1990), although these may be most effective if the emotion-eliciting stimuli are also p0270 relatively high in arousal. Investigations of the neural systems mediating arousal and valence have shown some clear dissociations between regions sensitive to valence vs arousal (e.g., Anderson and Sobel, 2003), but there may be some brain regions most sensitive to specific arousal–valence combinations (see, for example, Cunningham *et al*., 2008). One potential disadvantage of the using the Circumplex model to capture affective experience is that we rarely use dimensions of the emotion in everyday life. In discussing and describing emotion outside the laboratory, we tend to use more specific and nuanced descriptions of our affective state.

p0280 A second dimensional approach that is used less frequently by affective scientists but is particularly relevant to neuroeconomics is the approach/withdrawal distinction (Davidson *et al*., 1990; Davidson, 2000). This approach classifies different emotions according to motivation. One of the primary functions of emotion is to motivate action, and different emotional states lead to different goals for action. Some emotional states, such as happiness, surprise, and anger, are referred to as *approach* emotions – that is, they evoke a motive or goal to approach a situation. Other emotional states, such as sadness, disgust, or fear, are *withdrawal* emotions, in that there is a natural tendency is to withdraw from situations linked to these emotions.

s0150 MANIPULATING AND MEASURING EMOTION IN RESEARCH

p0290 Our ability to investigate the impact of emotion on economic decisions and other behaviors is necessarily limited by our ability to manipulate and measure emotion in the laboratory. Theories of the underlying structure of emotion, such as the component process model outlined in this chapter, make several distinctions that may not always be fully captured by the techniques available. In spite of these limitations, psychological and neuroscience research has identified several techniques proven to be effective in understanding the impact of components of emotion on cognition that may be useful in investigating the impact of emotion and affect on economic decisions.

s0160 Manipulating Emotion

p0300 The manipulation of emotion and affect in the laboratory is constrained by ethical standards that prevent us from eliciting strong emotional reactions in humans for research purposes. For this reason, corroborating evidence from research with animal models and examples or studies from outside the laboratory may be particularly important. Below, three common techniques are outlined.

Emotion-eliciting Stimuli s0170

Perhaps not surprisingly, the primary technique used to elicit emotion in the laboratory is to present p0310
emotionally evocative stimuli or situations. The question for emotion researchers is, what kinds of stimuli are most effective or appropriate to elicit the desired response? There are several classes of stimuli that have been well characterized and used across a range of studies.

Two classes of these stimuli are emotional scenes and words. Peter Lang and colleagues (1999) have p0320
developed a database with over a thousand complex scenes with varying emotional content, called the International Affective Picture System (IAPS). These scenes have been characterized by a large sample based on subjective ratings using the dimensions of valence and arousal. These norms obtained with subjective ratings have been confirmed for subsets of scenes with physiological measures that assess arousal and/or valence (Lang *et al*., 1990, 1993). More recently, Lang and colleagues developed a similar set of emotion-eliciting words, (Affective Norms for English Words – ANEW) and sounds (International Affective Digital Sounds – IADS). These stimuli are made freely available to interested researchers, and have been widely used in studies of emotion and cognition (http://csea.phhp.ufl.edu/media.html).

Another class of stimuli commonly used in emotion p0330
research consists of faces with emotional expressions. As mentioned earlier, the muscle patterns of the six basic facial expressions have been extensively studied and characterized. The presentation of these faces has been shown to elicit a range of emotional responses in the perceiver, including those assessed with facial muscle movements (Tassinary and Cacioppo, 1992), subjective judgments (Zajonc, 1984; Adolphs, 2002), and choices (Winkielman *et al*., 2005). Paul Ekman and colleagues have developed sets of pictures of facial expressions that have been used extensively in studies of emotion (http://www.paulekman.com/).

Other stimuli typically used to elicit emotion p0340
in laboratory studies would be considered *primary reinforcers* – that is, stimuli or situations that are inherently appetitive or aversive. For instance, mild electric shock is typically used in studies of conditioned fear (see, for example, LaBar *et al*., 1998), and threat of shock is used to elicit an anxiety response (Grillon and Davis, 1997). To assure that electric shock is

administered in an ethical manner, these studies generally use a work-up procedure in which participants indicate when the level of shock is "uncomfortable, but not painful." Other primary reinforcers used in research include juice for thirsty participants (Tobler *et al*., 2006), and food for hungry participants (LaBar *et al*., 2001; O'Doherty *et al*., 2006). One advantage of these primary reinforcers is that they are also used in studies with non-human animals, allowing investigation of emotional responses and neural systems using analogous tasks across species (see, for example, Phelps and LeDoux, 2005).

p0350 Another technique that might be considered a primary reinforcer in humans is to create social pressure or stress by presenting a social evaluation situation. In the Trier Social Stress test, research participants are asked to give a short public performance that will be evaluated. In some studies, participants are also asked to perform arithmetic in front of an audience. This brief social evaluation situation has been shown to elicit hormonal and physiological emotional responses (Kirschbaum *et al*., 1993).

p0360 A final technique that has been used in emotion research that is highly relevant to neuroeconomic research is to give or take away money. Money, by definition, is a *secondary reinforcer*, in that its reinforcing properties are tied to what it represents; however its prominence as a *cultural reinforcer* may give it properties more analogous to a primary reinforcer than to a typical secondary reinforcer. Although money is the incentive used most frequently in economic studies of value and choice behavior, the presentation or removal of money has also been shown to elicit physiological responses indicative of an emotional reaction (Delgado *et al*., 2006; Delgado *et al*., 2008).

s0180 ***Mood Induction***

p0370 Another technique that has been used to manipulate affect in the laboratory is focused on altering mood. This technique, called *mood induction*, attempts to change the baseline state reported by a research participant on coming into the laboratory, and to have this change in baseline mood persist throughout the experimental task. Typical means of changing a participant's mood are to present emotional film clips (e.g., scenes from a comedy routine to achieve a happy mood, or a death scene to achieve a sad mood), to play music that is depressing or upbeat, or to ask the subject to focus on emotional situations (real or imagined) that result in either positive or negative affect states, or a more specific state such as sadness or disgust (see, for example, Lerner *et al*., 2004). Mood-induction procedures are considered successful if the participant reports a shift of mood state in the predicted direction using a subjective mood assessment.

Pharmacological Manipulations s0190

A final technique that is not used frequently, but p0380
may be particularly useful in examining the neural basis of emotion, including neuroeconomic studies of emotion, is to introduce a drug that impacts emotion or social reactions. As described earlier, the classic study by Schacter and Singer (1962) mimicked a physiological arousal response by administering epinephrine. A pharmacological agent used in more recent human emotion research is propranolol, a beta-adrenergic antagonist that inhibits arousal responses in the body and brain. By administering propranolol, investigators have been able to further specify the impact of the physiological and neuromodulatory effects of arousal on memory and attention (Cahill *et al*., 1994; DeMartino *et al*., 2008).

A pharmacological agent that has been used previ- p0390
ously in neuroeconomic research is oxytocin. Oxytocin is a hormone that is primarily known for its role in social bonding (Insel and Young, 2001). In a recent study, administering oxytocin was shown to increase social risk in a trust game (Kosfield *et al*., 2005). Although oxytocin is primarily linked to social attachment, it has also been shown to impact emotional responses in social situations (Heinrichs, 2003). It has been suggested that the interaction of social cues and emotion may underlie some of the observed effects of oxytocin on behavior. A final pharmacological manipulation that may prove useful in future neuroeconomic and emotion research is to introduce dopamine agonists or antagonists, given the prominent role of dopamine in reward processing (see Chapter 21 of this volume). The advantage of pharmacological manipulations for neuroeconomic studies is that the impact of these drugs on the central nervous system is relatively well characterized by animal models. Because of this, they can provide unique insight into the neural mechanisms underlying emotion and decision-making.

Measuring Emotion and Affect s0200

Affective scientists have identified a range of tech- p0400
niques for assessing emotional experience. Most of these measure responses that are unique to emotion and affect, but some examine responses that could be indicative of range of behaviors, including emotion. One constraint of measuring emotion and affect in the laboratory is that it can be difficult to assess several types of emotional responses simultaneously,

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due to their complexity or to interference between the measures. In addition, the assessment of emotion may, at times, influence the affective state being measured. Given this, researchers have to determine which measure is most appropriate for the specific question being addressed or emotion manipulation used.

s0210 **_Subjective Report_**

p0410 The primary means used to assess emotion and affect both in and outside the laboratory is to ask. Measures of subjective report often use Likert scales and ask participants to rate their emotional or affective state, or their reaction to an emotion-eliciting stimulus. The specific aspect of emotional experience assessed varies across studies, but often reflects the basic or dimensional approaches to categorizing emotional experience described earlier. One potential difficulty in using subjective reports of emotion is the possibility that asking participants to reflect on their affective state may alter their appraisal of the affective experience.

s0220 **_Physiological Measures_**

p0420 One of the unique aspects of emotion, in relation to other types of behaviors, is that there are several physiological responses accompanying emotional experience that can be assessed in a relatively non-intrusive manner. These physiological assessments provide a powerful means to examine emotion, both because they are unique to emotion and because they may represent specific autonomic and neuromodulatory response patterns that can provide additional insight into the underlying neural mechanisms. Here, two types of physiological responses used in emotion research are described; however, readers are referred to the *Handbook of Psychophysiology* (Cacioppo *et al.*, 2000b) for more detail, as well as information on additional physiological means for assessing emotion and affect.

p0430 The *skin conductance response* (SCR) is an indication of autonomic nervous system arousal. When someone becomes aroused, even if it is subtle, the sweat glands respond. This creates a change in the electrical conductivity of the skin. SCR is usually assessed by placing electrodes on the participant's fingers that pass a small electrical current through the skin. The participant does not feel anything from these electrodes. The electrodes pick up on subtle changes in the electrical conductivity of the skin with autonomic arousal. One advantage of SCR is that it is non-intrusive; participants do not have to do anything other than keep their fingers still. In addition, SCR can be assessed during functional magnetic resonance imaging (fMRI), allowing for concurrent assessment of arousal and blood oxygenation-level dependent (BOLD) signal. One potential disadvantages of SCR is that it takes a few seconds for an SCR in reaction to an event to emerge, so the presentation of stimuli has to be separated by several seconds. In addition, other responses, such a button press, can interfere with the assessment of SCR. SCR is a measure of arousal that does not differentiate positive or negative valence, or more specific categories of emotion experience.

A physiological measure that can be used to assess more specific emotion categories is *electromyography* (EMG). EMG is primarily used to assess the response of facial muscles in reaction to emotion-eliciting events. There are two primary ways EMG is used in the assessment of emotion. The first is as an index of the magnitude of the startle reflex. Startle is a reflex response that occurs when an individual is surprised, such as when hearing a sudden loud noise. The startle reflex is stronger or potentiated when experiencing a negative affective state, and reduced or attenuated somewhat during a positive affective state (Lang *et al.*, 1990). This can be measured in the laboratory by examining the strength of the eyeblink response to a loud, white-noise startle probe. One component of the startle reflex is an eyeblink, and the strength of this eyeblink response is measured by electrodes placed on the skin over the muscles around the eyes. For example, the startle reflex has been used as a physiological measure to assess the valence of the IAPS scenes described earlier. A brief, loud white noise was presented to participants as they viewed negative, positive, or neutral scenes, and in response to this loud white noise they blinked. The strength of this eyeblink, as measured by EMG, demonstrated an enhanced or potentiated startle reflex while viewing the negative scenes, relative to neutral scenes, and a slightly attenuated startle reflex while viewing positive scenes (Lang *et al.*, 1990). Some advantages of the startle response as a physiological measure of emotion are that it is a discrete response that can be assessed quickly, and it can indicate valence. Some disadvantages are that the loud, white-noise probe can be aversive to participants, and its measurement is difficult during fMRI, both because the startle reflex elicits head movement and because the electrodes are on the face inside the bore of the magnet, leading to significant interference in the EMG signal. p0440

EMG has also been used to measure responses of muscles that indicate specific facial expressions. Given that the pattern of facial muscle movement differs for the six basic facial expressions described earlier, researchers have used EMG to assess facial p0450

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movements consistent with different expressions. By measuring the activity of only a few specific facial muscles, researchers can reliably differentiate positive and negative emotional reactions. Although more specific facial expressions can be detected, they require the measurement of additional muscle movements, and these more complex response patterns are less frequently assessed. The assessment of facial muscle movement as an indication of an emotional reaction does not require that the participant make a facial expression that is apparent by visual inspection; even subtle movements of facial muscles that do not result in an easily observable facial expression can be detected (Tassinary and Cacioppo, 1992). Advantages of this technique are that it is non-intrusive and does not require any response by the participant, and it can detect relatively subtle emotional responses the measurement of which is quick and discrete. One disadvantage is that it may be difficult to assess concurrently with fMRI.

s0230 *Other Assessment Techniques*

p0460 Another non-intrusive technique to assess facial expressions in response to emotional events is visually to observe the face and code the patterns of muscle movements. Paul Ekman and colleagues have developed a Facial Action Coding System (FACS) that trains researchers to detect the response of specific muscle movements of the face by visual inspection. With training in FACS, the researcher can videotape the facial expression of research participants and code which basic facial expression is expressed during different stages of the experiment. This technique requires, of course, that the facial muscle movement be apparent to visual inspection, although subtle muscle movements that do not result in the full expression pattern can often be reliably observed.

p0470 Another common assessment of emotion uses reaction time. Studies have shown that an emotion-eliciting event can both increase and decrease reaction time, depending on the task. When emotion leads to increased reaction time, it is suggested that emotion interferes or conflicts with task processing (see, for example, Pratto and John, 1991; de Martino *et al*., 2008). When emotion leads to a decrease in reaction time, it is suggested that emotion facilitates performance on the task (e.g. Öhman *et al*., 2001). One of the primary difficulties in using reaction time as a measure of emotion is that it is non-specific. Reaction-time differences are generally used as measure of mental processing speed that can be indicative of a number of cognitive, behavioral, and emotional processes. For this reason, it is important that, when using reaction time as a measure of emotion, the task design does not vary additional factors (e.g, complexity, conflict) along with the emotion variable of interest. In addition, reaction time cannot indicate which component of emotion or affect may be linked to any observed difference in processing speed.

The measure of emotion or affect that is used in current economic studies of decision-making is choice or action. The selection of one option over others is typically used as an indication of preference or attitude. The action taken in a task is used as an indication of an approach or withdrawal action tendency elicited by an emotion, mood, attitude, or preference. p0480

EMOTION AND AFFECT IN ECONOMIC AND NEUROECONOMIC RESEARCH s0240

Although there has been increasing interest in the interaction between emotion and decision-making, there are surprisingly few economic and neuroeconomic studies that have explicitly manipulated or measured emotion or affect variables. In many studies and theories, emotion is inferred, but not directly altered or assessed. However, there have been some attempts to examine emotion variables in studies of economic choice. Here, for each component of emotion or affect described earlier, one economic or neuroeconomic study that has measured or manipulated this emotion or affect variable is highlighted. Finally, the problem of inferring emotion from patterns of brain activation in neuroeconomic research is discussed. p0490

Emotion s0250

As outlined earlier there are several features that characterize an emotion. One critical feature differentiating emotion from mood is that it is a discrete response to an event. Differentiating emotion from attitude and preference is a little more complex due to overlapping features in response to an event, such as subjective experience and action tendencies. For each feature of emotion, one study that has assessed or manipulated this variable is described briefly. p0500

Subjective Experience s0260

One anomaly in economic decision-making is revealed in the ultimatum game, in which participants will reject a small monetary offer when the alternative is to receive nothing. A general interpretation of this effect is that when an offer is deemed to be unfair, the receiver will pay a cost to punish the offerer, who p0510

GLIMCHER 978-0-12-374176-9 00016

CH016.indd 242 5/9/2008 12:39:53 PM

receives nothing if the offer is rejected. It is suggested this type of altruistic punishment may play a role in maintaining social norms (Fehr and Rockenbach, 2004).

p0520 In an effort to determine whether emotion plays a role in the decision to reject unfair offers in the ultimatum game, Pillutla and Murnighan (1996) asked participants to rate the offers received both in terms of fairness and their subjective experience of anger at receiving the offer. They found that different factors (such as type of knowledge about the game) differentially influenced ratings of fairness and anger, although they were correlated. In addition, they found that anger was a better explanation of rejections than the perception that the offers were unfair. Using a measure that assessed the subjective experience of emotion, or feeling, these results identified an additional factor that may mediate decisions in an economic game. They suggest that when emotion features are assessed they may enhance our understanding of the processes underlying decisions.

s0270 *Expression*

p0530 There appear to be no studies that have assessed expression in the face, voice, or body as a measure of emotion in economic decision-making. However, a recent study by Winkielman and colleagues (2005) used facial expressions as emotion-eliciting cues to examine the impact of emotion on both the consumption of a beverage and the subjective rating of preference. The goal was to demonstrate that participants do not need to be consciously aware of an emotional stimulus or response for it to influence choice behavior.

p0540 In this study, participants were presented pictures of faces with neutral, happy, or angry expressions. These faces were presented very briefly, and were immediately followed by a neutral face. Using these procedures, participants were unaware of the presentation of the faces with emotional expressions. Following the presentation of the faces, they were given the opportunity to pour and drink a beverage. They were also asked to rate their subjective feelings using a scale assessing valence and arousal. In a second experiment using a similar procedure, participants were asked to indicate how much they were willing to pay for the drink and whether they wanted more of the drink.

p0550 The study found that the observed effects were strongest for participants who rated themselves as thirsty. These participants poured and drank more, were willing to pay more, and were more likely to want more when presented subliminal happy faces compared to neutral faces. The opposite pattern was observed when participants were presented subliminal angry faces. Interestingly, the subliminal emotion manipulation did not influence subjective judgments of affect, providing support for the suggestion that emotion's influence on choice behavior can be independent of the subjective experience of emotion.

Bodily Response s0280

One of the first and most influential neuroeconomics studies on emotion was the initial demonstration by Bechara and colleagues (Bechara *et al.*, 1997) that physiological indicators of arousal are correlated with choices in an economic gambling task, and that damage to the orbitofrontal cortex impairs both the physiological response and the choice behavior. p0560

The task used is known as the Iowa Gambling Task (IGT), and requires that participants pick a card from one of four decks over a series of trials. Each card selected represents a monetary reward or punishment, and the goal is to learn, through trial and error, which deck will yield a higher profit over time. The decks vary in their payoff schedules, with two of the decks (i.e. the "bad" decks) yielding greater rewards but also greater punishments, resulting in less overall profit than the other two decks (i.e. the "good" decks). Over a series of trials, normal, healthy participants eventually learned to select from the good decks more often than the bad decks, increasing their profits. Using SCR, physiological arousal was assessed as participants contemplated selecting from the good and bad decks. Higher arousal was observed prior to selecting from the bad decks. This enhanced arousal to the bad decks emerged prior to explicit knowledge about the reinforcement properties of the different decks. Bechara and colleagues (1997) suggested that it is this arousal response that steers participant away from the bad decks and promotes adaptive decisions. p0570

A second group of participants with damage to the orbitofrontal cortex failed to learn to select more from the good decks over time. These patients also failed to generate anticipatory arousal responses. The results from this simple task are consistent with clinical reports of patients with damage to this region showing impaired social and emotional decision-making in their daily lives. Based on these results, and others, Antonio Damasio (1994) proposed the Somatic Marker Hypothesis, which proposes that bodily states and emotional responses play a fundamental role in driving choice behavior. p0580

In the years since the groundbreaking study by Bechara *et al*. (1997), a number of investigators have challenged the claims of the Somatic Marker p0590

GLIMCHER 978-0-12-374176-9 00016

CH016.indd 243 5/9/2008 12:39:54 PM

Hypothesis, and the interpretation of the IGT task in particular (see Dunn *et al*., 2006 for a review). It has been proposed that the impairment observed with orbitofrontal cortex damage may be due to an inability to flexibly update stimulus–response contingencies, called reversal (Fellows and Farah, 2005). In addition, it has been suggested that explicit knowledge may underlie the observed pattern of choice behavior (Maia and McClelland, 2004), and that the relation arousal and choice is not specific (Tomb *et al*., 2002). Finally, it has been shown that impairments in autonomic feedback do not always result in poor performance on the IGT (Heims *et al*., 2004).

p0600 In spite of these concerns, the somatic marker hypothesis (Damasio, 1994) and the Bechara *et al*. (1997) study played a fundamental role in neuroeconomics and emotion. By assessing a physiological emotional response in an economic decision task and linking performance to human brain function, these findings highlighted the importance and value of considering brain function and emotion in efforts to understand economic decisions, at a time when these topics were rarely discussed.

s0290 *Action Tendencies*

p0610 The tendency to action is assessed by instrumental responses and choices, and it is in this way that most neuroeconomic studies assess this tendency. However, an especially powerful demonstration of an action tendency in emotion is the increased motivation to perform an instrumental response in the presence of an emotional cue that is unrelated to the instrumental response or choice. This change in motivation, sometimes referred to as *vigor*, is demonstrated in the Pavlovian-instrumental transfer paradigm (Rescorla and Soloman, 1967).

p0620 A recent neuroeconomic study examined the circuitry mediating Pavlovian-instrumental transfer in humans (Talmi *et al*., 2008). Through simple pairing (Pavlovian conditioning), participants were trained to expect a monetary reinforcement when one stimulus was presented (the conditioned stimulus, CS+), but not with another (the CS−). This pairing led to faster reaction times to, and a higher pleasantness rating for, the CS+. They were then trained to squeeze a handgrip to receive a monetary reward (instrumental conditioning). After partial extinction of the instrumental response, the Pavlovian-instrumental transfer test was conducted. In this final test stage the CS+ and CS− cues were presented at the same time as participants were given the opportunity to squeeze the handgrip. There was no monetary reinforcement in this final stage, so both the Pavlovian and instrumental responses were being extinguished. During this test phase, the participants squeezed the handgrip more frequently in the presence of the CS+ relative to the CS−. This increased frequency, or vigor, of the instrumental response in the presence of conditioned reward stimulus is indicative of an action tendency elicited by an emotion cue.

An examination of the pattern of BOLD response p0630 showed that activation of nucleus accumbens was related to the enhanced frequency of handgrip movements observed in the presence of the CS+. Across subjects, there was a correlation of the amygdala response and the magnitude of the Pavlovian-instrumental transfer effect. These results confirm studies from non-human animals suggesting that the action tendency elicited by conditioned emotional cues and expressed by instrumental responses may involve the interaction of the amygdala and striatum (Balliene, 2005). This type of enhanced motivation or action tendency in the presence of conditioned emotion cues is thought to play role in craving and drug-seeking (Everitt *et al*., 2001), as well as economic behavior.

Evaluation and Appraisal s0300

Changing how an event is appraised is fundamen- p0640 tal to studies of emotion regulation. By interpreting an event differently, the emotional response to an event can be altered (Ochsner and Gross, 2005). A recent study adapted an emotion-regulation technique to examine the impact of altering appraisal on economic decisions and emotional reactions (Curley *et al*., 2007). Participants were presented with a series of risky gambles and asked to choose between the gamble and a guaranteed outcome. For half of the gambles, participants were instructed to view each choice as one in a portfolio of choices. For the other half, they were instructed to focus on each choice as if it were the only option.

The portfolio strategy resulted in an overall p0650 decrease in loss aversion. In addition, the more loss averse a participant was, the higher the physiological arousal response (as assessed with SCR) to monetary losses relative to gains at outcome. Those participants who were more successful at decreasing loss aversion with the portfolio strategy also showed a greater decrease in their arousal response to losses with the strategy. These results show that a typical economic behavior, loss aversion, may be linked to an emotional response, arousal, and that changing the appraisal of a choice may impact both of these responses.

GLIMCHER 978-0-12-374176-9 00016

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s0310 ### Mood

p0660 Like emotion, mood can elicit action tendencies that may impact economic choices. In a demonstration of this, Lerner and colleagues (2004) induced moods of sadness and disgust and examined their impact on the endowment effect. Prior to the mood-induction procedure, half the participants were given a highlighter set for later use. Participants then watched one of three movies chosen to elicit a sad, disgusted, or neutral mood. To enhance the mood-induction manipulation, participants were also asked to write about how they would feel if they were in the situation depicted in the film clip. After the mood-induction procedure, they were asked how much they would sell (if endowed) the highlighter set for, or how much they would choose to pay for it (if not endowed). They then rated their mood on a questionnaire assessing the intensity of a range of affective states.

p0670 The participants in the neutral mood condition showed the classic endowment effect – that is, they would demand more to sell the product than they would choose to pay for it. The sad-mood group showed the opposite pattern; the sell price was lower than the choice price. Finally, the disgusted-mood group showed no endowment effect; sell and choice prices were equivalent. These results suggest that mood can have a powerful effect on economic choices. In addition, the effect is specific to different mood states. Additional studies have demonstrated that an angry mood has a unique impact on risk and decision-making (Lerner and Tiedens, 2006).

s0320 ### Attitudes and Preferences

p0680 Preferences are often assessed by the choice between options. This is how most neuroeconomic and economic studies assess an indication of preference. A recent neuroeconomic study also assessed the subjective judgments of preference and related these judgments to BOLD response patterns during a consumer purchasing task (Knutson *et al*., 2007). In this study, subjects were presented with a series of consumer items and a price, and were asked to decide whether they were willing buy the item at that price. After scanning, subjects rated the items on desirability (i.e. preference) and indicated the price they would be willing to pay for the item. These measures of preference and the price differential between asking price and the willingness to pay were used to assess the BOLD response patterns underlying the impact of preference and price on consumer purchases.

p0690 The primary region that correlated with preference was the nucleus accumbens, consistent with a role for this region in representing value. Two regions, the medial prefrontal cortex and the insular cortex, were correlated with the price measure, specifically excessive prices. BOLD responses in all these regions predicted purchasing decisions above and beyond the self-report variables. This study demonstrates the value of combining several different sources of information, such as subjective judgments of affect and price with brain-imaging results, to enhance the accuracy of predicting decisions.

Reverse Inference: Determining Emotion from BOLD Response Patterns s0330

One trend that has emerged in neuroeconomic studies of emotion that is far less prevalent and accepted in affective science broadly is the inference of emotion from a pattern of BOLD response (Cohen, 2005). This technique, called *reverse inference*, has often been used in brain-imaging studies as a *post hoc* method to explain unanticipated results. However, the use of reverse inference as the primary technique for assessing a behavioral or mental function in a task is relatively new. In a recent paper, Russell Poldrack (2006) examined the assumptions underlying the use of reverse inference in brain-imaging studies. Given the prominence of this approach in neuroeconomic studies of emotion, it is important to understand these assumptions and the strengths and weaknesses of this approach. p0700

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