

## Surprise

Author: Rainer Reisenzein

Institute of Psychology, University of Greifswald

Franz-Mehring-Str. 47

17487 Greifswald, Germany

E-mail: rainer.reisenzein@uni-greifswald.de

Telephone/Fax: +49 3834 863770 / +49 3934 863763

Co-Authors: Wulf-Uwe Meyer, Michael Niepel

Department of Psychology, University of Bielefeld

E-mail: wulf-uwe.meyer@uni-bielefeld.de; michael.niepel@uni-bielefeld.de

Telephone/Fax:

### Abstract

Surprise is the mental reaction to unexpectedness. Surprise is subjectively experienced as a characteristic feeling and may manifest itself in a variety of behaviors and physiological changes. It is argued that underlying these phenomena is an evolved mechanism whose function is to (a) detect discrepancies between cognitive schemas and newly acquired information, and (b) if they are detected, to instigate processes that enable the short- and long-term adaptation to them. Surprise must be distinguished from the startle reaction elicited by sudden, intense sensory input; as well as from the orienting reaction to novel or significant stimuli. Although the status of surprise as an emotion is controversial, surprise needs to be considered in theories of emotion even if it is not regarded as an emotion itself.

### Keywords

Emotion, belief, expectation, orienting response, misexpected, startle reaction, surprise, schema, unexpected

- I. Pretheoretical Characterization of Surprise
- II. A Short History of Research on Surprise
- III. Theories of Surprise. The Cognitive-Evolutionary Model
- IV. Surprise, the Startle Reaction, and the Orienting Response
- V. Is Surprise an Emotion?

### Glossary

**Belief:** The mental state of holding a proposition to be true; one of the basic kinds of propositional attitude.

**Expectation:** In common parlance, a belief regarding a future state of affairs. In the theory of surprise, “expectation” is used more broadly, as a synonym of “belief”.

**Emotions:** Mental states experienced as (typically positive or negative) feelings that typically seem to be directed at specific objects, and are more or less frequently accompanied by physiological arousal, expressive reactions (e. g. facial expressions), and characteristic actions. Examples are joy, sadness, hope, fear, anger, pity, guilt, and pride.

**Misexpected and unexpected:** Surprise is caused by unexpected events. Unexpected events cover two cases: Those that are misexpected, and those that are unexpected in the strict sense. An event is *misexpected* if it conflicts with a pre-existing, specific and usually explicit belief concerning this event. An event is *unexpected in the strict sense* if it is inconsistent with the person’s background beliefs.

**Orienting response:** The orienting response (OR) is usually defined as a probabilistic syndrome of behavioral and physiological reactions, evoked in particular by novel or significant stimuli. Although the reactions characteristic for the OR and those characteristic for surprise overlap, the OR must be distinguished from surprise.

**Schema:** According to schema theory, human perception, thought and action are to a large extent controlled by complex, organized knowledge or belief structures, called schemas. Schemas can be regarded as informal, unarticulated theories, or as sets of beliefs, about objects, events, event sequences (including actions and their consequences) and situations.

**Startle reaction:** A reflex-like defensive response elicited by abrupt, intense sensory input, such as a pistol shot. The startle reaction consists centrally of a rapid muscular response beginning with the closure of the eyes, that may extend to the body; but it also includes a variety of physiological changes. Although surprise is a frequent secondary reaction to startling stimuli, the startle reaction and surprise are entirely different phenomena.

**Surprise:** A peculiar state of mind, usually of brief duration, caused by unexpected events of all kinds. Subjectively, surprise manifests itself centrally in a characteristic feeling; objectively, it may manifest itself in a variety of behaviors and physiological changes. It is argued that underlying these phenomena is an evolved mechanism whose function is to (a) detect discrepancies between cognitive schemas and newly acquired information, and (b) if they are detected, to instigate processes that enable the short- and long-term adaptation to them.

## I. PRETHEORETICAL CHARACTERIZATION OF SURPRISE

Common-sense psychology conceptualizes surprise as a peculiar state of mind, usually of brief duration, caused by unexpected events of all kinds, ranging from unexpected sounds and lights to unexpected social events (e. g., the outcome of an election), to unexpected turns in novels and unexpected puns of jokes.

*Subjectively* (i. e., from the perspective of the surprised person), surprise manifests itself centrally in a phenomenal experience or “feeling” with a characteristic quality, that can vary in intensity from just-noticeable to intense. In addition, the surprised person is often aware, at least if she observes herself carefully, of a variety of surprise-related mental and behavioral events: She realizes that something is different from usual or other than expected; she notices that her ongoing mental processes and actions are being interrupted and that her attention is drawn to the unexpected event; she may feel curiosity about the nature and causes of this event; and she may notice the occurrence of spontaneous epistemic search processes (attempts to make sense of the event).

*Objectively* (i. e., from the perspective of the outside observer), surprise may reveal itself—depending on circumstances—in any of a number of behavioral indicators, including: interruption or delay of ongoing motor activities; orienting of the sense organs to the surprising event; investigative activities such as visual search or questioning others; spontaneous exclamations (“Oh!”) and explicit verbal proclamations of being surprised; and a characteristic facial expression consisting, in full-

blown form, of eyebrow-raising, eye-widening, and mouth-opening/jaw drop. Intercultural studies suggest that people from different cultures consider this facial display to be characteristic for surprise; this points to an evolutionary origin of the expression. Psychophysiological studies suggest that surprising events may also elicit a variety of bodily changes, similar to those characteristic for the orienting response (OR), such as a temporary slowing of heart rate and an increased activity of the eccrine sweat glands [see below: ORIENTING RESPONSE]. As to the brain processes that underlie surprise, research is limited; again however, the available evidence suggests that the neurophysiological events characteristic for surprise overlap partly with those characteristic for the OR. In particular, electrophysiological studies suggest that the so-called P300a component of evoked brain potentials elicited by rare deviant stimuli may also be characteristic for (some forms of) surprise [see below: ORIENTING RESPONSE]. Brain imaging studies suggest that both unexpected stimuli and rare deviant stimuli activate a large network of cortical and subcortical regions in the brain, suggesting a “whole brain response” to unexpectedness that would fit well with the theory of surprise detailed below, as well as with theories of the OR. As to the brain processes selectively associated with surprise, a recent study points to processes in the lateral prefrontal cortex.

Scientists can use the various external indicators of surprise (self reports about surprise, action delay, brain responses etc.) to infer the presence and intensity of surprise in their research participants. It must be noted, however, that the behavioral manifestations of surprise (e. g., the facial expression of surprise, or physiological reactions) occur by no means in all surprise-eliciting situations and are in general only loosely associated with one another. Although progress in brain imaging techniques may eventually provide researchers with a precise, objective measure of surprise, for the time being the most direct indicator of surprise remains the person’s self-report about the presence and intensity of the feeling of surprise, typically measured using a rating scale (ranging e. g., from “0” = not at all surprised to “10” = extremely surprised”).

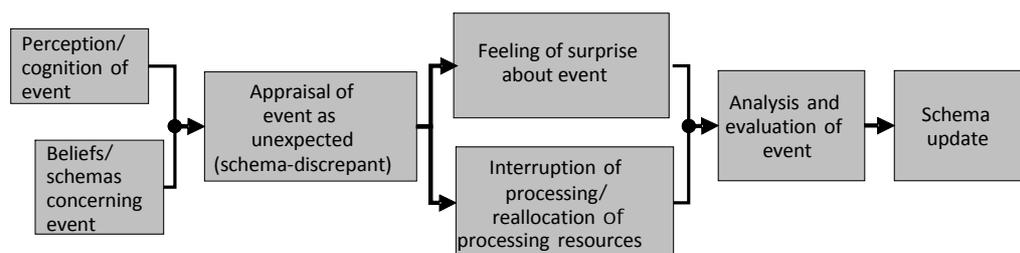
## **II. A SHORT HISTORY OF RESEARCH ON SURPRISE**

Descriptions of surprise as a mental and behavioral phenomenon, as well as first attempts at theory-building, date back as far as Aristotle (about 350 B.C.). Among the first to discuss surprise in modern times were the philosophers David Hume and Adam Smith in the 18<sup>th</sup> century. Their ideas were taken up and elaborated further when psychology was established as an independent discipline in the 19<sup>th</sup> century. By 1920, most of the questions about surprise that are discussed today had already been formulated, and even first experimental studies had been conducted. However, during the subsequent, behaviorist era of psychology (about 1920-1960), research on surprise came largely to a standstill, to be taken up again only following the so-called “cognitive revolution” of the 1960s. At that time, aspects of surprise first came to be discussed again under the headings of “orienting response” [see below: ORIENTING RESPONSE] and “curiosity and exploration”. Surprise as an independent phenomenon was first discussed anew by evolutionary emotion theorists Silvan Tomkins and Carroll Izard. Referring back to Darwin, these authors proposed that surprise is a basic emotion that serves essential biological functions. One of these functions—surprise as an instigator of epistemic (specifically causal) search and a precondition for learning and cognitive development—came to be particularly emphasized by developmental psychologists. This suggestion was subsequently taken up by social psychologists interested in everyday causal explanations, who emphasized unexpectedness as a main instigator of spontaneous causal search. In the 1980s, cognitive psychologists, including cognitively oriented emotion theorists, became interested in surprise. Since that time, research on surprise has steadily increased and is carried out today by researchers in several different subfields of psychology, as well as in neighboring fields such as

artificial intelligence. Topics addressed by contemporary research on surprise (part of which is carried out under different labels such as “spontaneous attention”, “orienting response”, and “curiosity”) range from the relation of surprise to spontaneous attention capture, to the conditions of the facial expression of surprise, to the role of surprise in advertising. Because surprise is involved many different psychological phenomena, research on surprise is relevant for many areas of psychological investigation. These include belief updating and learning, the diagnosis of knowledge structures in children, spontaneous attention, automatic versus controlled processing, emotions, humor, the psychology of music, and aesthetic appreciation.

### III. THEORIES OF SURPRISE. THE COGNITIVE-EVOLUTIONARY MODEL

Classical psychological theories of surprise are formulated exclusively on the “intentional level” of system analysis familiar from common-sense psychology, using concepts such as *belief*, *expectation*, *attention* and, of course, *surprise*. Only in recent times have there been attempts to move beyond this level of analysis to the level of the underlying mental mechanisms, or the cognitive architecture. The aim of these newer, “process models” of surprise is to provide a deeper understanding of the causal generation of surprise, its nature, and its functional role in the architecture of the mind, by describing (at least in outline) the information-processing mechanisms that underlie the experience of surprise and surprise-related mental events and behaviors. To illustrate, we describe in some detail the *cognitive-evolutionary model of surprise* proposed by W.-U. Meyer and co-workers, which is the result of an attempt to integrate and elaborate the modal views of previous surprise theorists, as well as previous psychological analyses of humans’ reactions to unexpected events, within the framework of schema theory. This model has formed the basis of some recent empirical research on surprise in psychology, as well as inspired a computational model of surprise proposed by artificial intelligence researchers. The cognitive-evolutionary model of surprise is depicted in simplified form in Figure 1.



**FIGURE 1** A cognitive-evolutionary model of surprise. After W.-U. Meyer, R. Reisenzein, & A. Schützwohl (1997). Towards a process analysis of emotions: The case of surprise. *Motivation and Emotion*, 21, 251-274.

*Schema theory* assumes that human perception, thought and action are to a large extent controlled by complex, organized knowledge (or belief) structures, called schemas [see SCHEMA THEORY]. Schemas can be regarded as informal, unarticulated theories, or as sets of beliefs, about objects, events, event sequences (including actions and their consequences), and situations. Schemas serve

the interpretation of present and past, and the prediction of future events, and thereby the adaptive guidance of action. To be able to fulfill these functions, a person's schemas or informal theories must be at least approximately correct. This in turn requires—because knowledge of the environment is usually incomplete, and because the environment can change—that schemas are continuously monitored for their compatibility with newly acquired information and, if necessary, are appropriately updated. According to the cognitive-evolutionary model of surprise, the surprise mechanism plays a crucial role in this context.

The surprise mechanism is assumed to consist at its core of an innate, hardwired information processing device that continuously compares, at an unconscious level of processing, the currently activated cognitive schemas (which may be regarded as constituting the person's working-memory model of her present situation) with newly acquired information (new beliefs). As long as the "schema-discrepancy detector" registers congruence between schema and input—colloquially, as long as events conform to expectations—the person's informal theories are supported by the evidence, and there is hence no need to revise them. Rather, the interpretation of events and the control of action take place largely automatically and effortless. In contrast, if a discrepancy between schema and input is detected, and if the degree of schema-discrepancy (unexpectedness) exceeds a certain threshold, a "surprise reaction" is elicited (see Figure 1): Ongoing information processing is interrupted, processing resources are reallocated to the unexpected event, and the feeling of surprise is generated (Figure 1). These processes enable and prepare the subsequent analysis and evaluation of the unexpected event plus—if this analysis suggests so—immediate reactions to this event and/or the updating, extension, or revision of the schema or schemas that gave rise to the discrepancy (Figure 1). The evolutionary function of the surprise mechanism is to (a) detect schema-discrepancies and (b) if they are detected, to prepare and instigate processes (of event analysis and schema revision) that enable the immediate and long-term adaptation to unexpected events. Let us look at the processes postulated in Figure 1 in more detail.

### **A. Detection of Schema-Discrepancies**

The assumption that surprise is caused by the detection of schema-discrepancies is an explication of the common-sense psychological assumption—which is accepted by nearly all classical and modern surprise theorists—that surprise is elicited by *unexpected events*, that is, by events that disconfirm, contradict, or violate an expectation. However, to cover all cases of surprise, this idea is given an extended interpretation in the theory that includes the following assumptions: (1) The "expectations" that are disconfirmed by surprising events are not restricted to beliefs about the future; rather, "expectation" is used as a synonym of "belief". This assumption is necessary to take account of the fact that surprise can also be caused by disconfirmation of beliefs about the past (e. g., one is surprised that the train has already departed) and about atemporal states of affairs (e. g., one is surprised that a particular theorem follows from the axioms of a theory). (2) The concept of "unexpectedness" covers two cases: *misexpectedness*, and *unexpectedness in the strict sense*. An event is *misexpected* if it conflicts with a pre-existing, specific and usually explicit belief concerning this event. For example, Mary is waiting for Bob in her office; hearing a knock at the door, she expects Bob to enter, but Bill enters instead. This event elicits surprise because it is *misexpected*. In contrast, an event is *unexpected in the strict sense* if it does not conflict with an explicitly held belief (at least none that was active, that is, in the person's working memory at the time when the surprising event occurred), although it is inconsistent with the person's background beliefs. For

example, even if Mary does not expect anybody in particular to visit her, she will be surprised to see Bill walk into her office if she believes that Bill currently attends a conference abroad. (3) The explicit or implicit beliefs whose disconfirmation causes surprise can be acquired in several different ways: They can be gradually built up through personal experience during an extended period of time (e. g., during many days in her office, Mary learns that Bob usually visits her at noon); they can be conveyed through verbal communication (Bob informs Mary that he will come to visit her at noon); and they can be inferred from other beliefs through reasoning processes (e. g., Mary reasons that, because Bob has promised to visit her the next time he is in town, and because he is in town today, will probably visit her today).

Any plausible cognitive theory of surprise must take account of these facts. This means in particular that such a theory needs a suitably general and flexible account of the internal representations that serve as a reference against which an event is classified as “discrepant”. This account must allow to represent beliefs about past, present and future states of affairs; as well as beliefs about concrete events and abstract states of affairs; it must allow to explain how both misexpected and unexpected events can be classified as “discrepant”; and it must be able to accommodate different sources of belief acquisition (e. g., cumulative personal experience over an extended period of time, and explicit verbal information). The schema concept promises a description of adequate breadth: Surprising events are those not consistent with currently activated schemas, irrespective of the existence of a concrete expectation, and irrespective of the origins of the beliefs encoded in the schema. Schema theories postulate that schemas become activated as a result of current experiences (that may include the unexpected event itself). The activated schemas then serve as a reference against which experiences are; events that deviate from the currently activated schemas elicit surprise.

## **B. Interruption, Reallocation of Processing Resources, Event Analysis, and Schema Update**

Usually the individual is engaged in some other activity when an unexpected event occurs. To permit the undisturbed processing of the unexpected event, these ongoing cognitive and motor activities are temporarily interrupted by the surprise mechanism, and the available processing resources are redistributed, now favouring processes that serve the analysis of the event and the updating of currently activated schemas. The focusing of attention on the unexpected event amplifies information relevant for the updating process and simultaneously attenuates potentially interfering information from other sources. It should be noted that, although turning attention to the surprising event as a prerequisite for updating is in most cases adaptive, it is not always so, because there are situations in which even the shortest interruption of momentary activity can have disastrous effects. This is the case when the uninterrupted continuation of ongoing activities is vitally necessary, as may be the case for a fighter pilot or a cat burglar. From the perspective of the cognitive-evolutionary model of surprise, these occasional negative side-effects of surprise are the price that has to be paid for a mechanism that is overall adaptive in enabling the coping with unexpected events.

According to the cognitive-evolutionary model of surprise, the subsequent analysis and evaluation of the surprising event typically comprises the following subprocesses: the verification of the schema discrepancy (did one see or hear right; did one draw the correct conclusion from premises?); the analysis of the causes of the unexpected event (why did it happen?); the evaluation of the unexpected event’s significance for well-being (is the event congruent or incongruent with one’s desires; does it signal danger, or an unexpected opportunity?); and the assessment of the event’s

relevance for ongoing action (can one ignore the event, or does one need to respond to it?). Additional event appraisal, such as an assessment of the moral significance of another person's unexpected action, can also occur in special situations. Once the appraisals of an unexpected event (e. g., regarding its causes or action relevance) have been computed, they are stored as part of the schema for this event. As a consequence, the analysis of subsequent instances of the same or similar kinds of events can be substantially abbreviated.

The analysis and evaluation of the surprising event is usually a precondition for adaptive schema (or belief) update. A schema update may consist in the correction, restructuring or extension of relevant schemas. Appropriate schema-update enables the individual: to predict and possibly, to control (bring about or prevent) future occurrences of the schema-discrepant event; to avoid the event if it is negative and uncontrollable; or to ignore the event if it is irrelevant for further action. The long-term function of surprise is thus to ensure the adaptation of the individual by enabling and instigating processes that result in the updating of action-guiding schemas. To the degree that schema revision or belief-update can be equated with cognitive development and learning, it follows that surprise should have an important function for the development of cognitive structures and learning. In agreement with this conclusion, many developmental psychologists consider surprise to be an important factor for children's' cognitive development [see COGNITIVE DEVELOPMENT]. Similarly, several learning theorists conceive of learning as a process in which an individual's schemas are brought into line with new input that deviates from the schemas. This suggests that at least one central form of learning—namely belief updating—occurs only if newly acquired information is unexpected and hence surprising. Surprise theory thus suggests a strongly "localist" approach to belief updating.

### **C. The Behavioral Manifestations and the Experience of Surprise**

The cognitive-evolutionary model of surprise assumes that the described mental processes are causally responsible, alone or in combination, for the various behavioral manifestations of surprise (if they occur): The interruption or delay of ongoing motor activities, investigative activities, facial and verbal expressions of surprise, and peripheral physiological reactions. For the greater part, these behavioral manifestations of surprise are probably adaptive processes that, in one way or another, subserve the major function of the surprise mechanism: the short- and long-term adaptation to unexpected events. For example, investigative motor actions are in the service of epistemic analysis, and eyebrow-raising may, as Darwin argued, facilitate the visual exploration of unexpected events in some situations. In addition, eyebrow-raising could serve to communicate the person's surprise to others, thereby soliciting their help in explaining the unexpected event. Indeed, a deliberately produced, stylized form of the surprise expression—raising the eyebrows to form an enquiring look—is frequently used as a nonverbal request for information in everyday conversation. In this way, the facial expression of surprise (and likewise surprise vocalizations) may assist the updating of beliefs by recruiting informational support from the social environment.

The subjective experience or "feeling" of surprise can be regarded as the manifestation in consciousness of the encountered discrepancy between activated schema and newly acquired information. Because the intensity of experienced surprise is closely related to the degree of unexpectedness of the eliciting event, the feeling of surprise could simply be the conscious awareness of the signal produced by the schema-discrepancy detector. (According to the model,

this signal is characterized by a specific quality that codes the fact that a schema discrepancy has occurred, and an intensity that codes the degree of the schema-discrepancy.) However, the subjective experience of surprise could include additional elements, such as a direct phenomenal awareness of mental interruption.

According to the cognitive-evolutionary model of surprise, the feeling of surprise has an informational as well as a motivational function. Its *informational function* consists of informing the conscious self (the person) about the detection of a schema-discrepancy. This assumption relates to theoretical views of consciousness that stress the importance of consciousness for planning: Whereas the routine execution of simple activities may be carried out without conscious control, the generation of action plans for exceptional situations requires conscious processing. Seen from this perspective, the surprise signal acts on the one hand as a “deautomatizer” that interrupts routine processes and calls for, as well as prepares, conscious processing; on the other hand, the surprise signal enters conscious processing (in the form of the surprise feeling) as information about the occurrence of a schema-discrepancy. In addition to its informational function, the experience of surprise can also be ascribed a *motivational function*, for it is likely the feeling of surprise that triggers the conscious analysis of the surprising event, or at least provides an initial impetus for this analysis. The reason for this is probably that the information that something unexpected happened, elicits curiosity. Hence, the motivational effect of the surprise feeling may be based on its informational effect.

#### **D. The Theoretical Definition of Surprise**

The cognitive-evolutionary model of surprise allows to replace the pre-theoretical characterization of surprise by a more precise, theoretical (i. e., theory-based) definition. As evident from Figure 1, the schema-discrepancy signal is the “causal hub in the wheel of surprise”: It is the direct or indirect cause of all subsequent mental processes postulated in the model (the feeling of surprise, interruption and attentional shift, event analysis, and schema revision), as well as of the various behavioral manifestations of surprise. Because of its central causal role, the schema discrepancy signal suggests itself as the best candidate for the scientific referent of surprise. Hence, presupposing the correctness of the cognitive-evolutionary model of surprise, surprise can be theoretically defined as follows: *Surprise is the signal that is the immediate output of the schema-discrepancy detector.*

### **IV. SURPRISE, THE STARTLE REACTION, AND THE ORIENTING RESPONSE**

#### **A. The Startle Reaction**

Surprise must be distinguished from the so-called *startle reaction* elicited by sudden intense sensory input. The startle reaction differs from surprise in terms of its causes, its topography, and its function.

Whereas surprise is elicited by the appraisal of unexpectedness (the detection of a schema-discrepancy), startle is a reflex-like reaction to abrupt, intense sensory input, such as a pistol shot. “Abruptness” in this context does *not* mean unexpectedness, but primarily a sudden onset and fast rise of the intensity of sensory input. For example, an acoustic stimulus (a tone or noise) with a high peak intensity will elicit startle only given a short rise time (in the range of some 10 msec), but not when it rises gradually. Furthermore, whereas the intensity of surprise is determined by the degree of unexpectedness, the magnitude of the startle

reaction is mainly determined by the intensity of the sensory input. Because of these differences in eliciting conditions, a sensory stimulus that elicits startle (i. e., one with abrupt onset and high intensity) need not cause surprise (if it has been announced beforehand, or presented repeatedly); and a sensory stimulus that elicits surprise (i. e., one that is unanticipated or contrary to expectations) need not cause a startle response (if it is of low intensity, or if its intensity rises gradually). However, surprise is a frequent secondary reaction to startling stimuli, because these stimuli are often unexpected as well. It is probably for this reason that the ordinary language word “startle” can also be used to refer to some forms of surprise.

Surprise and startle also differ in terms of the typical behaviors associated with them. The startle reaction consists, centrally, in a specific pattern of facial and bodily muscle movements, varying considerably in completeness, that spreads from the head over the rest of the body. Its initial and most reliable component is the reflexive closure of the eyes; but if the reaction is more intense, it may include additional facial movements (lowering of the eyebrows and a horizontal stretching of the mouth) and postural changes: A forward motion of the head and neck, hunching of the shoulders, pronation of the lower arms, flexion of the fingers, bending of the elbows and knees, contraction of the abdomen, and a forward motion of the trunk. These muscular reactions are accompanied by diverse physiological changes including an increase in skin conductance, blood pressure, and heart rate, plus an initial holding of breath followed by accelerated respiration. With the exception of the skin conductance reaction, these physiological changes are different from those attributed to surprise. Likewise, the postural changes characteristic for startle are quite untypical for surprise, and the facial changes that occur in startle (closure of the eyes, lowering of the eyebrows, stretching of the mouth) are even opposite to those characteristic for surprise (widening of the eyes, raising of the eyebrows, dropped open jaw). In addition, the temporal onset of the startle reaction differs from that of surprise: Whereas surprise needs at least 200-300 ms to develop in response to a sensory input (e. g., an unexpected tone), the startle reaction occurs with very short latency, with its earliest components appearing at some 40 msec after the onset of a startle stimulus.

Correlated to these differences in elicitors and response, the functions of surprise and startle are different: Whereas the function of surprise is to assist the updating of schemas or beliefs, the startle reaction is—as suggested by the short latency and topography of the described muscular response pattern—essentially a first-line defensive reflex against injury from a predator or a blow. In line with this conclusion, the neural pathways underlying the startle reaction have been determined to consist of a brain-stem reflex system that exists, in similar form, not only in humans but also in variety of animal species.

## **B. The Orienting Response**

The orienting response (OR) is typically defined as a probabilistic syndrome of responses, evoked in particular by novel and significant stimuli, that includes a variety of behavioral and physiological components, the latter being of primary interest to most researchers of the OR. Although the reactions characteristic for the OR and those characteristic for surprise overlap, the OR must be distinguished from surprise.

The conditions that evoke the OR have been classified into three broad categories. The first category, *novelty* (the quality of an event or stimulus of being new), can be subdivided into (a) novelty of a stimulus or an elementary event, (b) novelty in a sequence of events, and (c) novelty in the patterning of stimuli. For example, a tone that is presented for the first time in an experiment is novel in the first sense; a tone that deviates occasionally from a

sequence of regular tones (a so-called “oddball stimulus”) is novel in the second sense, and a melody that deviates from one heard before would be novel in the third sense. The second category, *conflict*, refers to situations in which an ambiguous stimulus leads to the activation of conflicting response tendencies (e. g., in a difficult perceptual discrimination task). The last category, *previous conditioning*, includes high-importance stimuli (e. g., one’s own name or a warning call like “watch out”), which have acquired their significance as a result of the individual’s learning history. In contrast to the startle response, the OR does not require an increase in the intensity of stimulation to occur. In fact, an event evoking an OR can consist of the occurrence, as well as the change, and even the removal (or omission) of a stimulus (e. g., the omission of a tone in a regular series).

Although there is overlap in the typical procedures used to induce either the OR or surprise in humans, they are not identical. In particular, not all events that elicit an OR also elicit surprise. A novel stimulus, as defined above, may well cause surprise, the reason being that novel stimuli are often also unexpected; however, novel stimuli can also be expected (e. g., an oddball stimulus that has been announced beforehand, or has been presented repeatedly), in which case they do not elicit surprise. And stimuli from the “conflict” or the “previous conditioning” categories of OR elicitors need not be unexpected, and hence surprising at all. However, it is possible that all events that cause surprise also trigger an OR (or a special form of the OR), in which case the physiological changes that occur in surprise could consist of the physiological aspects of the OR.

The behavioral components of the OR include movements of the sense organs toward the source of the eliciting stimulus, as well as an interruption of overt actions, accompanied by an increase in general muscle tonus. The physiological components of the OR comprise (a) an increased sensitivity of the sense organs, manifested in the lowering of sensory thresholds; (b) vegetative changes (a decrease of heart rate and respiration rate, an increase in skin conductance, and two opposing vascular changes, vasoconstriction in the limbs and vasodilation in the head); and (c) changes in the electroencephalogram [see BRAIN ELECTRIC ACTIVITY] in the direction of faster activity with a lower amplitude, indicative of an increase in cortical arousal or wakefulness.

As to the specific brain processes that underlie the OR, it has been found that novel events evoke a cortical response that differs in waveform from that caused by regular events. More specifically, this research (which has mostly studied the electrocortical responses to simple auditory or visual oddballs) has identified three characteristic components of the event-related brain potential evoked by these oddballs. The first is the so-called mismatch negativity, a negative peak around 200 ms after stimulus onset, which is thought to reflect the pre-attentive, automatic detection of the sensory (e.g., acoustic) change. The second is the P300a component (a positive peak around 350 ms after stimulus onset) that seems to reflect the involuntary attention switch to the oddball event. Third, the so-called reorienting negativity (a negative peak around 500 ms after stimulus onset), is thought to reflect the voluntary attentional reorienting to the task at hand. Brain imaging studies found that oddball stimuli elicit widespread activity in diverse, spatially distributed cortical and subcortical systems. To the degree that these brain responses also occur in response to unexpected events, they would indicate that surprising stimuli elicit a “whole-brain response” that would fit well with the function attributed to surprise. As mentioned, the brain processes selectively associated with surprise proper (the output signal of the schema-discrepancy detector) may be localized in the lateral prefrontal cortex [see above: PRETHEORETICAL CHARACTERIZATION OF SURPRISE].

## **V. IS SURPRISE AN EMOTION?**

Common-sense classifies surprise as an emotion. In contrast, in scientific psychology, the question of whether or not surprise is an emotion is controversial: Some emotion theorists regard surprise not only as an emotion, but even as a basic emotion; others regard it as an emotion, but not a basic one; and yet others do not classify surprise as an emotion at all, but as a cognitive state (although one that may play an important role in the process of emotion generation, e. g., by preparing the individual for the evaluative appraisal of events).

Surprise is typically considered a basic emotion by proponents of an evolutionary approach to emotions, in particular the adherents of the theory of “discrete basic emotions”. Basic emotion theorists believe that the innate core of the human emotion system consists of a small set of modules—the basic emotion mechanisms—each of which developed in evolution as a solution to a different, recurrent adaptive problem. Surprise, they argue, fits this definition of basic emotions. Some theorists assume, in addition, that basic emotions are innately linked to communicative signals, in particular to facial expressions. Inasmuch as surprise is indeed associated with a specific facial expression, it would also qualify as a basic emotion according to this criterion.

Two main arguments have been advanced for *not* regarding surprise an emotion: (1) in contrast to paradigmatic emotions such as joy or fear, the feeling of surprise is per se hedonically neutral, rather than pleasant or unpleasant; (2) corresponding to, and explaining, this difference in feeling tone, surprise does not presuppose the appraisal of the eliciting event as positive (motive-congruent) or negative (motive-incongruent). The claim that surprise is hedonically neutral rests on the observation that the experience of surprise can be pleasant (e. g., surprise caused by an unexpected present), unpleasant (e. g., an unexpected failure), as well as neutral (neither pleasant nor unpleasant; e. g., surprise about an unexpected solution of a quiz item). This observation suggests that feelings of pleasantness and unpleasantness are not a necessary component of surprise, but result from processes different from those that elicit surprise. These other processes, that are responsible for the hedonic tone of surprise in those cases where it is either pleasant or unpleasant, can be construed as appraisals or evaluations of the significance of what is happening for one’s well-being; specifically, the evaluation of the surprise-eliciting event as positive (motive-congruent) or negative (motive-incongruent). This appraisal of motive-consistency, if it occurs at all, usually takes place in parallel to, or quickly after the onset of surprise, and it results in pleasant or unpleasant feelings that blend with the feeling of surprise in consciousness, thus endowing the experience of surprise with a positive or negative hedonic quality. This hypothesis allows to explain the differences in feeling tone in different instances of surprise. It also explains why some authors have come to think that surprise, like other emotions, is intrinsically hedonic or evaluative.

Although the proposed differences between surprise and paradigmatic emotions must be acknowledged, it is not clear whether they are great enough to exclude surprise from the realm of emotions. For one reason, surprise appears to be an essential ingredient of several unquestioned emotional states, such as disappointment and relief; and the intensity of most emotions is enhanced if their elicitors occur unexpectedly. For another reason, it can be argued that the cognitive mechanism that produces surprise (a mechanism that compares newly acquired beliefs to pre-existing beliefs) and the mechanism that produces hedonic emotions (presumably, a mechanism that compares new beliefs to pre-existing motives or desires) have similar properties and are closely intertwined in their operation: They are both automatically and unconsciously operating mechanisms that “supervise” representations (beliefs and desires, respectively); they seem to

operate on the same inputs (newly acquired beliefs); and their outputs may be integrated at an unconscious level of processing (e. g., the signals of unexpectedness and desire-incongruence may be unconsciously integrated into the emotion of disappointment). If these assumptions are correct, they would constitute good theoretical reasons for (re-) classifying surprise as an emotion. In any case, however, surprise needs to be considered in theories of emotion, even if it is not regarded as an emotion itself.

## References

### Cross References

Belief, Brain electrical activity, cognitive development, belief update, expectation, emotion, schema theory, cognitive representation, learning, evolutionary psychology, curiosity, computational modelling, humor, creativity.

### Further Reading

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### Relevant Websites

### Author Biography and Photograph

Rainer Reisenzein is Professor of General Psychology at the University of Greifswald, Germany. His research focuses on the psychology of emotions, where he investigates a variety of theoretical and empirical questions, including: the cognitive causes of emotion, emotional experience, the facial

expression of emotion, and the psychology of surprise. He was previously a member of Wulf-Uwe Meyer's research group on the psychology of surprise. His most recent work concerns the formulation of a computational model of the belief-desire theory of emotion, that incorporates several central ideas from the earlier model of surprise developed by Meyer and co-workers. Rainer Reisenzein is co-author, together with Wulf-Uwe Meyer and Achim Schützwohl, of a German three-volume text book on the psychology of emotions. For more information, see <http://www.phil.uni-greifswald.de/sozial/psychologie/lehrstuehle/allgemeine-psychologie-ii.html>

Wulf-Uwe Meyer is Professor Emeritus of General Psychology at the University of Bielefeld, Germany. His research area is the psychology of motivation and emotion. Initially his research focussed on the psychology of achievement motivation from an attribution theory perspective, specifically the role played by the self-concept of ability. Later research investigated apparently paradoxical effects of praise and blame. In the 1990ies, Wulf-Uwe started a research program on surprise as an emotion, and proposed an integrative model of surprise from a schema-theory perspective. Together with Achim Schützwohl and Rainer Reisenzein as co-authors, Meyer has written a three-volume German text book on the psychology of emotions.

Michael Niepel holds a Ph. D. in psychology from the University of Bielefeld, Germany. He was for several years a member of the research group of W.-U. Meyer on surprise, and has conducted his Ph. D. research on the relation of surprise to the physiological orienting reaction. He is author or co-author on several journal articles and book chapters on surprise. Currently, Michael Niepel is a psychological consultant and free-lance scientific writer in Bielefeld.