

Glossary

A note about the abbreviation *ERP*: The abbreviation *ERP* is sometimes used incorrectly in the singular form (mostly by native English speakers) and is sometimes used incorrectly in the plural form (mostly by nonnative English speakers). The key is that *ERP* should usually be written in the plural form when used as a noun and in the singular form when used as an adjective. For example, one conducts an “ERP study” and not an “ERPs study,” because in this situation *ERP* is used as an adjective. Conversely, one conducts an experiment “with fMRI and ERPs” not “with fMRI and ERP,” because in this situation *ERP* is used as a noun (after all, one would not say that an experiment was conducted “with functional magnetic imaging and event-related potential”). Also, *ERP* stands for *event-related potential*, not *evoked response potential* (which appears to be a miscombination of *evoked response* and *evoked potential*, much as *irregardless* is a miscombination of *regardless* and *irrespective*).

Alpha

In statistics, this is criterion that you have chosen for statistical significance (usually 0.05).

Alternative hypothesis

The hypothesis that the conditions are actually different (i.e., the means of the conditions would differ if we could measure from an infinite number of subjects).

Anti-aliasing filter

A low-pass filter that is specifically designed to avoid aliasing during the digitization process.

Auditory brainstem response (ABR)

These are small and fast ERPs elicited by auditory stimuli such as clicks, occurring within the first 10 ms after stimulus onset and arising from the early stages of the ascending auditory pathway. They are frequently used in clinical audiology. They are also called *brainstem evoked responses* (BERs) or *brainstem auditory evoked responses* (BAERs).

Band-pass filter

A filter that passes an intermediate range of frequencies and attenuates frequencies that are below or above this range. A band-pass filter is equivalent to sequentially applying a low-pass filter and a high-pass filter.

Block of trials

A series of trials, typically followed by a rest break. Also called a *run* or a *trial block*.

Brainstem auditory evoked response (BAER)

See *Auditory brainstem response*.

Brainstem evoked response (BER)

See *Auditory brainstem response*.

CDA

See *Contralateral delay activity*.

Common mode rejection

The ability of a differential amplifier to subtract away the contribution of the common mode voltage (the voltage that is shared between the ground electrode and the other electrodes). It is measured in decibels (dB), and a larger value means that more of the common mode voltage is eliminated.

Component

An underlying neural response that sums together with other neural response to produce the observed waveforms at the scalp electrodes. A given component is often linked with a specific positive or negative peak in the observed waveform, but this link is often tenuous. A component may be defined conceptually as “scalp-recorded neural activity that is generated in a given neuroanatomical module when a specific computational operation is performed” (chapter 2). Similarly, it may be defined as “a subsegment of the ERP whose activity represents a functionally distinct neuronal aggregate” (Donchin, Ritter, & McCallum, 1978, p. 353). It may also be defined operationally as “a set of potential changes that can be shown to be functionally related to an experimental variable or to a combination of experimental variables” (Donchin et al., 1978, p. 353).

Conductance

The ability of a substance to allow current to pass through (the inverse of *resistance*).

Contralateral

On the opposite side. The brain is mainly organized in a contralateral manner, in which one side of the brain receives inputs from the opposite side of space and controls muscles on the opposite side of the body.

Contralateral delay activity (CDA)

A sustained ERP component observed during the delay period of working memory tasks, defined by the difference in voltage between electrodes over the contralateral and ipsilateral hemispheres relative to the objects being maintained in working memory.

Cosine wave

A waveform that reflects the X value of a circle for a given angle of arc on the circle. See *Sine wave* for additional details.

Current

The flow of charges through a conductor.

Decibel (dB)

A logarithmic scale that is most commonly applied to sound waves but is also frequently applied to EEG and ERP waveforms. In the decibel scale, a doubling of power is equal to an increase of 3 dB. If we double the power twice (quadrupling the power), this will be an increase of 6 dB. Because power is amplitude squared, doubling the amplitude is equivalent to quadrupling the power. Therefore, doubling the amplitude is equivalent to a 6 dB increase. A 10-fold increase in power is an increase of 10 dB, and a 10-fold increase in amplitude is an increase of 20 dB.

Dipole

A pair of positive and negative charges, separated by a small distance.

Differential amplifier

An amplifier that amplifies the difference between an active site and a reference site. The active site is initially the electrical potential between the active electrode and the ground electrode, and the reference site is initially the potential between the reference electrode and the ground electrode. The difference between these two electrical potentials (voltages) is amplified, which subtracts away the influence of the ground electrode. This subtraction is not completely perfect, and some small contribution of the ground electrode remains (see *Common mode rejection*).

Differential recording

A recording made by a differential amplifier, in which the ground is subtracted away and the recording represents the electrical potential (voltage) between the active electrodes and a reference electrode. This contrasts with a *single-ended recording*, in which the reference is not subtracted during the recording.

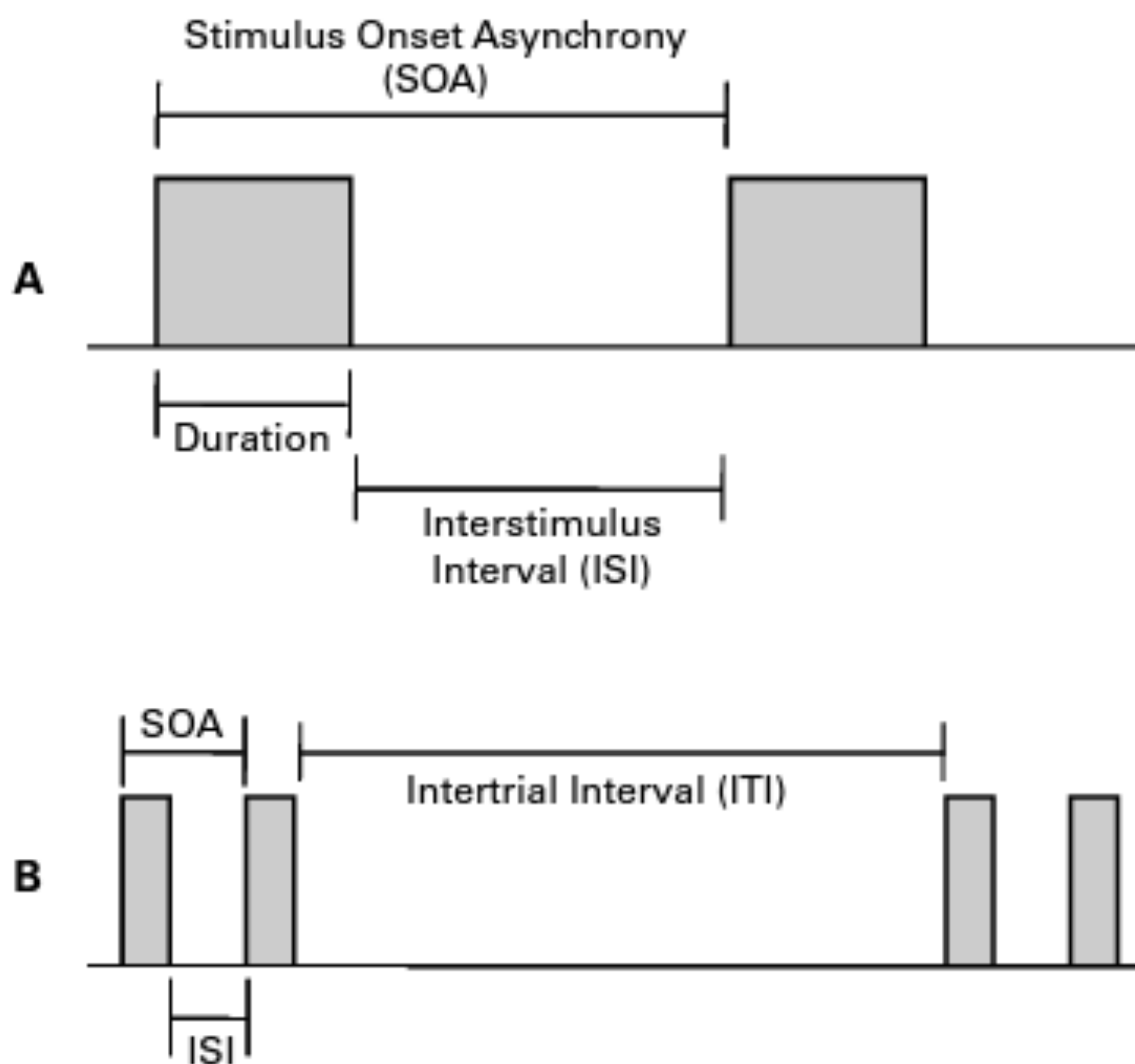


Figure G.1
Terminology for describing the timing of an ERP experiment.

Discrete Fourier transform (DFT)

A version of the Fourier transform that is applied to discretely sampled data (e.g., digitized EEG data and ERPs) rather than to continuous functions.

Downie

Informal (and ironically juvenile) term for a downward-going voltage deflection.

Duration

When describing stimuli, this is the amount of time between the onset of a stimulus and the offset of a stimulus (see figure G.1). When describing ERPs, this is the amount of time between the onset and the offset of a component or effect.

Electrical potential

See *Voltage*.

Electroencephalogram (EEG)

The electrical fields that are generated in the brain and propagate to the surface of the scalp.

Electromyogram (EMG)

Electrical activity generated by a muscle, which can be recorded at a distance by electrodes on the surface of the skin over the muscle.

Event-related magnetic field (ERMF)

The magnetic field that accompanies an event-related potential, as recorded via the magnetoencephalogram. The strength of the ERMF at a given time point is proportional to the strength of the corresponding ERP.

Event-related potential (ERP)

An electrical potential (voltage) that is related to an event (usually a stimulus or a response). This term replaced *evoked potential* for non-obligatory brain potentials in the late 1960s. The earliest published use of the term “event-related potential” that I could find was by Herb Vaughan, who in a 1969 chapter wrote,

... Since cerebral processes may be related to voluntary movement and to relatively stimulus-independent psychological processes (e.g., Sutton et al., 1967, Ritter et al., 1968), the term “evoked potentials” is no longer sufficiently general to apply to all EEG phenomena related to sensorymotor processes. Moreover, sufficiently prominent or distinctive psychological events may serve as time references for averaging, in addition to stimuli and motor responses. The term “event related potentials” (ERP) is proposed to designate the general class of potentials that display stable time relationships to a definable reference event. (Vaughan, 1969, p. 46)

Related terms include: *evoked potential (EP)*, *evoked response*, *brainstem evoked response (BER)*, *brainstem auditory evoked response (BAER)*, *auditory brainstem response (ABR)*, *Somatosensory evoked potential (SEP)*, *visual evoked potential (VEP)*.

Evoked potential (EP)

An early term, which is still often used for obligatory sensory responses. The idea is that evoked potentials are electrical potentials that were *evoked* by stimuli (as opposed to the spontaneous EEG rhythms). This term was replaced in the late 1960s with *event-related potential* for non-obligatory cognitive-related responses. The term *evoked response* is equivalent to *evoked potential*.

Evoked response

See *Evoked potential*.

Evoked response potential (ERP)

This is apparently an accidental miscombination of *evoked response* and *event-related potential* (analogous to combining *irrespective* and *regardless* into *irregardless*). Not recommended.

Excitatory postsynaptic potential (EPSP)

A *postsynaptic potential* in which the net flow of positive charges is inward, bringing the cell closer to the threshold for firing.

Experimentwise error rate

The probability that at least one p value among all the p values in the statistical analyses for a given experiment will be a false positive.

Familywise error rate

The probability that at least one p value among all the p values for a given family of statistical analyses will be a false positive.

Filter

A device or process that removes or attenuates some part of a signal. This term is usually used for devices or processes that attenuate specific frequency bands, but it can be used more broadly. For example, the ADJAR (adjacent response) filter removes the overlapping ERPs from previous and subsequent stimuli.

Fast Fourier transform (FFT)

A computationally efficient method for performing a discrete Fourier transform that can be used when the number of points in the waveform is a power of two (e.g., an ERP waveform consisting of 256 time points).

Fourier transform

A mathematical procedure for decomposing a continuous waveform into the sum of a set of sinusoids of specific frequencies, amplitudes, and phases. The components can also be represented by pairs of sine and cosine waves at each frequency, each with a different amplitude. The phase of the corresponding sinusoid is related to the relative amplitudes of the sine and cosine waves. See also *Discrete Fourier transform* and *Fast Fourier transform*.

Grand average

An average across the single-subject averaged ERP waveforms for all the subjects in an experiment (in within-subject designs) or all the subjects in a group (in between-group designs).

High-pass filter

A filter that passes high frequencies and attenuates low frequencies. Often used to attenuate skin potentials and other slow changes in the EEG.

Impedance

The ability of a substance to keep an alternating current from passing through. A combination of resistance and inductance/capacitance.

Inhibitory postsynaptic potential (IPSP)

A *postsynaptic potential* in which the net flow of positive charges is outward, bringing the cell farther from the threshold for firing.

Interstimulus interval (ISI)

This is the amount of time between the offset of one stimulus and the onset of another stimulus (see figure G.1).

Intertrial interval (ITI)

This is the blank period between the offset of the final stimulus (or the response) in one trial and the onset of the first stimulus in the next trial (see figure G.1). This is equivalent to the *interstimulus interval* in simple experiments with only one stimulus per trial.

Ipsilateral

On the same side. A lesion of the left hemisphere, for example, would be ipsilateral to the left ear and *contralateral* to the right ear.

Lateralized readiness potential (LRP)

An ERP component related to motor preparation that is defined by the difference in voltage between electrodes of the contralateral and ipsilateral electrodes relative to the side of the response.

Line noise

Electrical noise arising from devices powered by the building's main electrical system and reflecting the frequency of this system (either 50 or 60 Hz).

Latency jitter

Trial to trial variations in the timing of one event relative to another event (e.g., variations in the timing of an ERP component relative to a stimulus).

Local field potential (LFP)

An electrical potential recorded from an electrode inside the brain that consists of the summed postsynaptic potentials of nearby neurons.

Low-pass filter

A filter that passes low frequencies and attenuates high frequencies. Often used to avoid aliasing prior to digitization or to attenuate high-frequency noise arising from electronic devices or muscle activity.

LRP

See *Lateralized readiness potential*.

Magnetoencephalogram (MEG)

The magnetic fields that accompany the EEG but are not blurred by the resistance of the skull.

Multi-unit recordings

Recordings of the action potentials from a group of nearby neurons.

Noise

In ERP research, *noise* refers to random variations in the ERP waveform that are unrelated to the brain activity that you are trying to record. For example, electrical activity in the recording chamber that is picked up by the recording electrodes causes variations in the ERP waveform that are not systematically related to the experimental conditions. Alpha oscillations are a form of brain activity that are a source of noise in many experiments, because they cause variations in the ERPs that are unrelated to the experimental manipulations. However, alpha oscillations can also be a signal, the dependent variable that is expected to vary systematically across the experimental conditions (or across subject groups, etc.). It is important to realize that one person's noise may be another person's signal. Any variations in the waveform that are unrelated to the brain activity of interest but are systematic rather than random are not usually considered to be noise, but are instead considered to be confounds.

Notch filter

A filter that attenuates a specific narrow band of frequencies and passes frequencies that are both higher and lower than this band. Often used to attenuate line noise.

Null hypothesis

The hypothesis that two or more conditions are actually equivalent (i.e., the means of the conditions would be exactly the same if we could measure from an infinite number of subjects).

***P* value**

A value returned by a statistical test that we use to decide whether or not to reject the null hypothesis and conclude that there is a real difference between conditions. This is done by comparing the *p* value with the alpha level (which is typically 0.05). If $p < \alpha$, we conclude that the null hypothesis is false and the alternative hypothesis is true. In theory, this means that we will falsely reject the null hypothesis with a probability of alpha (0.05).

Postsynaptic potential (PSP)

An electrical potential produced in a neuron when a neurotransmitter binds with a receptor, opening or closing ion channels and altering the flow of charged ions into or out of the neuron. Postsynaptic potentials are excitatory (EPSPs) if the net flow of positive charges is inward, bringing the cell closer to the threshold for firing. Postsynaptic potentials are inhibitory (IPSPs) if the net flow of positive charges is outward, bringing the cell farther from the threshold for firing.

Potential

See *Voltage*.

Power

In electrical circuits, power is the ability to get work done, and it is equal to the voltage multiplied by the current. In EEG/ERP research, power is simply the voltage squared (because the current is assumed to be proportional to the voltage). Power can be converted back into voltage by taking the square root, although the sign of the voltage may be incorrect (because, for example $-3^2 = 9$ and $\text{sqrt}(9) = +3$). The term *power* is also used in statistics for a completely different purpose (see *Statistical power*).

Resistance

The ability of a substance to keep a constant current from passing through (the inverse of *conductance*).

Run

See *Block of trials*.

Sine wave

A waveform that reflects the Y value of a circle for a given angle of arc on the circle. This is illustrated in figure G.2. A sine wave has a frequency, which represents how many times the sine wave repeats in a given period of time (e.g., 10 repetitions per sec, or 10 Hz). A sine wave also has an amplitude, which is the height of the peaks. A sine wave also has a phase, which is the horizontal shift in the waveform. A cosine wave is identical to a sine wave, except shifted in phase leftward by 90°. See also *Cosine wave*.

Signal-to-noise ratio (SNR)

A measure of data quality, in which the size of the signal is divided by the size of the noise. For example, if the signal of interest is 10 μV and the noise has a peak-to-peak amplitude of 2 μV , we would say that the SNR is 10:2, which is the same as 5. This means that the signal is 5 times larger than the noise.

Single-ended recording

A recording of the electrical potential (voltage) between an active electrode and a ground electrode, without subtracting the reference electrode. This contrasts with a *differential recording* (see *Differential amplifier*). Some systems (e.g., BioSemi ActiveTwo) initially provide a single-ended recording, and the reference is subtracted offline.

Single-unit recordings

Recordings of a single neuron's action potentials, typically obtained from an electrode just outside the cell body.

SOA

See *Stimulus onset asynchrony* and figure G.1.

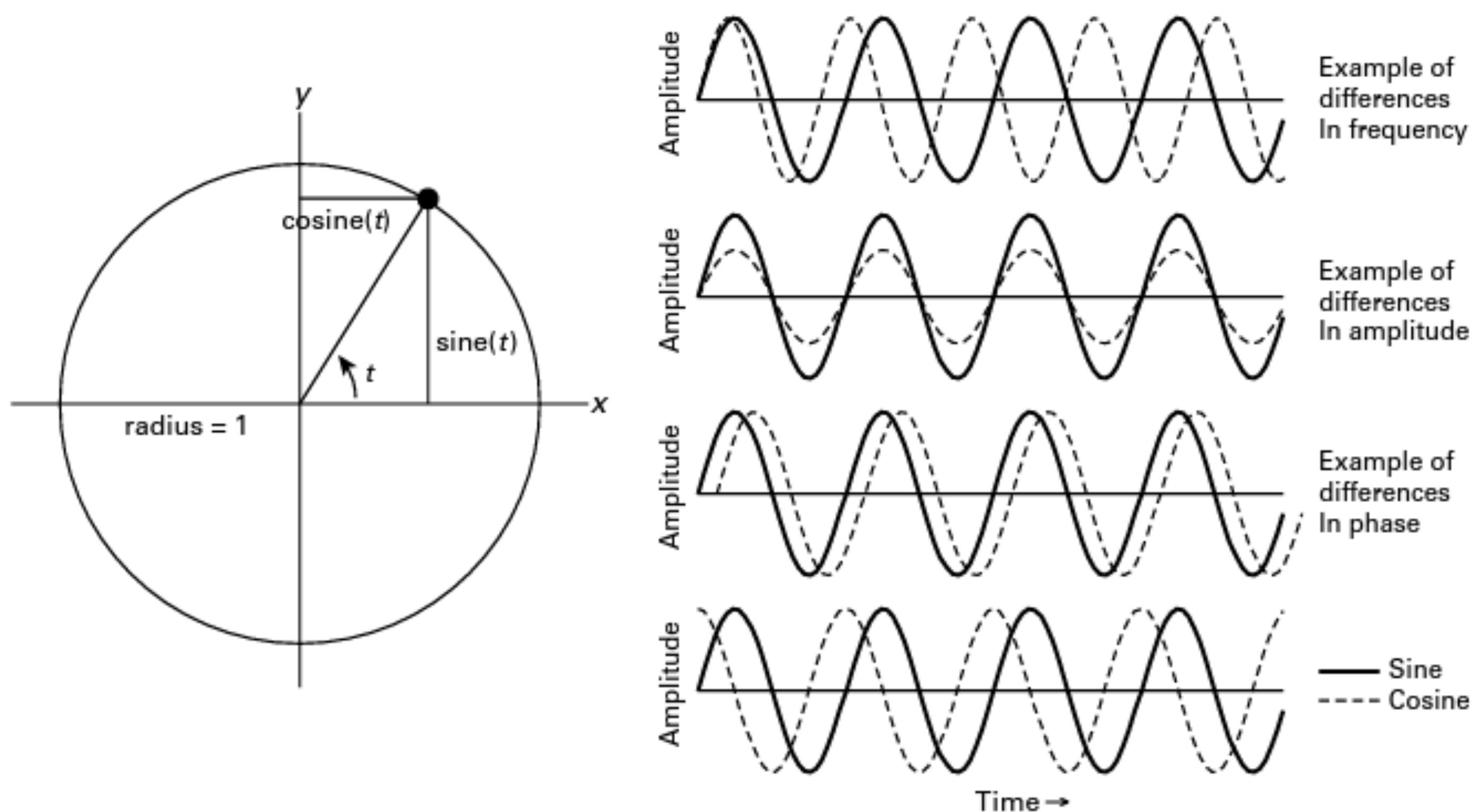
**Figure G.2**

Illustration of sine and cosine. The left side shows how sine and cosine are the Y and X values, respectively, of a point on a circle at a given angle (t). That is, the sine of angle t is the Y value of the location of a point at that location on the circle, and the cosine of angle t is the X value of that point. The right side shows plots of sine and cosine waves (i.e., the value of the sine or cosine function as the angle varies). Sine waves can vary in frequency (number of repetitions per second, which reflects how fast the point is moved around the circle). They can also vary in amplitude (which reflects the radius of the circle). They can also differ in phase (which reflects the degree of rotation of the circle). A cosine wave is simply a sine wave that has been shifted in phase leftward by 90° .

Statistical power

This is the probability that you will obtain a significant p value if the null hypothesis is false. If there is a true effect in the infinite population, random variability will sometimes cause the p value to be non-significant (a Type II error). The statistical power is a way of determining the likelihood that this will occur. High power means that it is unlikely that we will have a Type II error. Low power means that, even if an effect is present, we are unlikely to achieve statistical significance. Statistical power can be increased by several factors, including increasing the number of subjects in an experiment, increasing the number of trials per subject, etc.

Steady-state auditory evoked response (SSAER)

These are ERPs that are elicited by auditory stimuli that are presented at a constant and relatively fast rate, so that the auditory system begins to oscillate at the stimulus presentation rate (and harmonics of this rate).

Steady-state visual evoked potential (SSVEP)

These are ERPs that are elicited by visual stimuli that are presented at a constant and relatively fast rate, so that the visual system begins to oscillate at the stimulus presentation rate (and harmonics of this rate).

Stimulus duration

See *Duration*.

Stimulus onset asynchrony (SOA)

The interval between the onset of one stimulus and the onset of another stimulus (see figure G.1).

Trial block

See *Block of trials*.

Type I error

This is a false positive in a statistical analysis, in which we reject the null hypothesis (i.e., conclude that the effect is real) when the null hypothesis is actually true (i.e., when there is no true effect). The probability of a Type I error should be the alpha level (e.g., 0.05) if all the assumptions of the statistical test are met. That is, when there is no effect, you will falsely conclude that an effect is present 5% of the time if you use an alpha of 0.05.

Type II error

This is a false negative in a statistical analysis, in which we accept the null hypothesis (i.e., conclude that there is no effect) when the null hypothesis is actually false (i.e., when there is a true effect). Note that accepting the null hypothesis does not ordinarily allow any strong conclusions to be drawn. It is not positive evidence that there is no effect; instead, it just means that we do not have sufficient evidence to reject the null hypothesis. Thus, conventional statistics do not allow you to “prove the null hypothesis.”

Uppie

Informal (and ironically juvenile) term for an upward-going voltage deflection.

Visual evoked potential (VEP)

This term is commonly used in clinical contexts to describe largely automatic ERPs elicited by visual stimuli that are used to assess pathology in the visual system, such as demyelination caused by multiple sclerosis. A variant on this term is *visual evoked response* (VER).

Voltage

The potential for current to flow through a conductor. No current will actually flow unless the resistance of the conductor is sufficiently low. If the resistance is low enough, the voltage is essentially the pressure that pushes charges through the conductor (see *Electrical potential*).