

REVIEW ARTICLE

Health benefits of laughter and humor - Does simulated laughter have health benefits?

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Summary

Laughter and smiling are characteristic human behaviors that may have health benefits. Laughter is deeply connected to human emotions, and also serves various social functions. Physiological, endocrinological, psychological, and social perspectives must be considered when examining the health benefits of laughter. Various health benefits have been expected from laughter resulting from humor, and studies are underway on both the physiological basis and neural basis in the brain. Despite the reported health benefits of laughter interventions, no strict distinctions have been made between laughter and humor. This paper adds a discussion of the health effects of simulated laughter and the suggestion of the possibility that even inauthentic simulated laughter may also have health-promoting effects.

Key words: *laughter, smile, simulated laughter, health benefit, neural basis*

‘He who has not laughed all day is one who has wasted a day.’

-Sir Charles Spencer Chaplin (1889-1977)

INTRODUCTION

Laughter and smiling are human behaviors expressing pleasure and joy. Typical laughter occurs spontaneously from external stimuli such as humor or funny things, and it is often difficult to suppress voluntarily. Smiling is typically spontaneous but it can also be used voluntarily as part of social interaction in daily life. Whereas smiling is primarily a movement of the facial musculature alone, laughter also features this characteristic facial movement but accompanied by vocalization and thoracic movements. Laughter is typically a strong, spontaneous expression, while smiling is a comparatively gentle, controlled expression. Both are considered physiological responses that promote a sense of well-being, but laughter has a more powerful physiological effect than smiling. Although they share many common social functions, laughter has the effect of strengthening social bonds and reducing tension and conflict, while smiling is sometimes used as a means of showing courtesy and friendship. Characteristics that distinguish laughter and smiling by expression, frequency, motor intensity, social function, contagiousness, and physiological

response are shown in Table 1.

This paper focuses upon the health benefits of simulated laughter, but laughter and smiling have much in common. It is difficult to fully distinguish between them because they share the same facial muscle group movements that are characteristic of simulated laughter. Basic natural laughter is laughter induced by humor, however, and in this respect natural laughter and simulated laughter differ greatly. With these points in mind, we first discuss the classification of laughter, its neurophysiology, neural basis, and neuroanatomy. Then, we discuss the social significance of humor, information processing, neuroanatomy, and neural basis of humor, followed by discussion of the possibility of health effects of laughter and simulated laughter.

LAUGHTER

Classification of laughter

Darwin wrote “It would be surprising if laughter, the loud, defenseless behavior seen in humans, had no survival value. The evolutionary significance of laughter is its function as a social expression of happiness, which enhances group cohesion and is advantageous to group survival” (Darwin, 1872).

Ontogenetically, human smiles are first seen at 5 weeks of age (Kraemer, 1999), and laughter appears at around 4 months (Ruch, 2001). Laughter is

Table 1. Characteristics of laughter and smiling

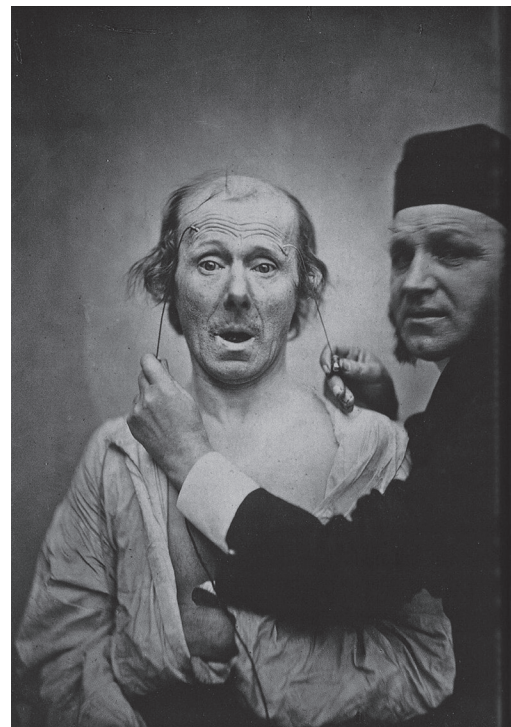
	Laughter	Smiling
representation	Often accompanied by vocalizations and body movements in addition to facial expressions, and contractions of the abdominal muscles and diaphragm	Smiling is a facial expression that uses mainly the muscles around the mouth and eyes
frequency	Less frequent than smiling and occurs with specific stimuli or situations (humor, social cohesion, etc.)	Smiling is frequently used in a variety of everyday social interactions and is considered an expression of courtesy and friendship
strength	Laughter is stronger than a smile, more spontaneous and harder to suppress	Smiling is usually a milder, more controlled expression than laughter
social function	Laughter strengthens social bonds, eases tension, and serves as a means of showing agreement and empathy	Smiling is used as a means of showing friendship, approval, courtesy, and reassurance, and sometimes to mask discomfort or nervousness
contagiousness	Easily contagious and can spread within a group	Smiling is rarely contagious to those around the person.
physiological response	Laughter reduces stress, boosts the immune system, and promotes the release of endorphins and other hormones	Smiling can also stimulate the release of endorphins and bring about a sense of well-being, but the effect is not as strong as laughter

not unique to humans and is also observed in other primates. In young chimpanzees, for example, playful faces and associated vocalizations resembling laughter have been observed (van Hoof, 1972; Preuschoft, 1995), and the neural basis of laughter has been much studied in squirrel monkeys (Jürgens, 1998).

Although laughter and smiles are diverse and morphologically more than 16 types can be distinguished (Ekman, 1997), authentic spontaneous laughter is called 'genuine laughter', 'true laughter', or 'Duchenne laughter'. Guillaume Duchenne de Boulogne (1806-1875), the founder of French neurology, reproduced the facial expression of laughter by applying electrical stimulation to facial muscles (Figure 1). This so-called 'Duchenne smile', smiling with the eyes, which more typically occurs in response to humor, is characterized by simultaneous contraction of the zygomaticus major and orbicularis oculi muscles. This creates an expression that pulls the edges of the lips backward and upward, it narrows and wrinkles the eyes, and it also activates the facial, respiratory and laryngeal muscles (Bachorowski, 2001; Ruch, 2001).

The electroencephalogram (EEG) electromyography (EMG) research group lead by Prof. Akira Shimizu of the Department of Psychiatry, Osaka University, devised a microelectrode to measure EMG of facial expression muscles, and they have published studies measuring the facial expression muscle activity of laughter (Tanaka, 1991; Sakamoto, 1997; Takahashi, 2001; Iwase, 2002). A three-category classification of laughter is shown in Table 2 (Shimizu, 2001), in which laughter is broadly classified as pleasant laughter, social laughter, or tension-relieving laughter. Pleasant laughter is sub-classified into five categories: instinctual satisfaction, expectation satisfaction, superiority, incongruity, and value reduction/reversal. Laughter of

instinct, expectation fulfillment, and superiority correspond with Duchenne Laughter, and tension-relieving laughter can also be understood as spontaneous laughter. On the other hand, incongruity and laughter of devaluation/reversal correspond with humorous laughter. We examined the intervention effects of laughter on elderly people and proposed that the laughter therapy inducing the pleasant type laughter is useful, even for elderly people with cognitive decline (Takeda, 2010).

**Figure 1.** Duchenne laughter

Guillaume Duchenne de Boulogne (1806-1875) showed that electrical stimulation of facial muscles can reproduce the facial expression of laughter. In the photograph, Duchenne (right) applies the stimulation electrodes held in both hands to the subject to reproduce the facial expression of laughter. (https://gigazine.net/news/20170412-smile/#google_vignette)

Table 2. Classification of laughter by Shimizu (2001)

Category	Laughter type	Example Situations
A. Laughter of Pleasant feeling	A1. Fulfillment of instinctive needs	appetite, sexual desire
	A2. Fulfillment of expectations	passing examinations or winning competitions
	A3. Feelings of superiority	showing off superiority to others
	A4. Feelings of disharmony	reaction to unexpected results, or mistaken understandings
	A5. Devaluation/ Reversal of value	lower positioned person looks down the superior
B. Laughter of Social relationship	B1. Cooperative	greetings, saying farewell
	B2. Defensive	preventing to reveal inside feeling
	B3. Aggressive	blaming other's failure, weakness, or immorality
	B4. Devaluating	devaluation of disadvantageous happenings
C. Laughter of Tension release	C1. Release from strong tension	release from strong stress
	C2. Release from weak tension	ticklings, puns

Neurophysiology of laughter

Laughter may have physiological effects similar to aerobic exercise because it involves vocalization and respiratory movement of the thorax, but there is a lack of data (Bennett, 2008). Muscle activity associated with laughter differs from most exercise in that certain muscle groups contract for a few seconds before relaxing, and there is decrease in muscle tonus. Muscle group relaxation after laughter can last up to 45 minutes (Paskind, 1932), so the primary effect of laughter can be assumed to bring muscle groups into a relaxed state.

Laughter also affects the respiratory system, eliciting deep breathing and increased respiratory rate (Fry, 1977). Effects on the circulatory system are also known, with strong laughter eliciting an increase in heart rate and oxygen consumption. This is similar to aerobic exercise, but these effects of laughter are temporary (Fry, 1988). Regarding the mechanism of muscle relaxation following laughter, laughter has been shown to alter the Hoffmann reflex (H-reflex), and both spontaneous and simulated laughter decrease spinal motor excitability. Natural laughter has been suggested to suppress the H-reflex more than simulated laughter, and the pleasant sensation itself apparently induces muscle relaxation after laughter by suppressing the H-reflex.

According to the James-Lange emotion hypothesis (Mandler, 1962), strong emotions elicit sympathetic nervous system arousal regardless of their content. In another study, heart rate, blood pressure, respiratory rate, skin temperature, and galvanic skin response were measured. Humorous and sad movies resulted in an increase in galvanic skin response, indicating sympathetic nervous system activity, but an increase

in blood pressure was seen only as a result of watching sad movies and not from watching humorous movies (Averill, 1959). Although humor increases sympathetic nervous system activity, it is suggested to have a buffering effect on blood pressure increases.

The effects of laughter on the endocrine system have also been investigated. Laughter decreases serum cortisol, growth hormone, and 3,4-dihydroxyphenylacetic acid levels, but does not change serum prolactin, serum beta-endorphin, serum epinephrine, or serum norepinephrine levels. Laughter may therefore moderate the effects of stress on the immune system by lowering stress hormones (Berk, 1988; Berk, 1989).

In summary, laughter causes an immediate increase in heart rate, respiratory rate, depth of breathing and oxygen consumption, followed by relaxation of muscle groups, which leads to a decrease in heart rate, respiratory rate, and in blood pressure. Data on changes in stress hormones is still insufficient, but laughter is assumed to affect the endocrine and immune systems and to exert health effects.

Neural basis of laughter - pathological laughter

The activity of facial muscles in laughter is unique. Studies have focused on laughter induced compulsively by pathological conditions and have attempted to elucidate the neural basis of laughter in relation to specific diseases and brain lesions.

It has long been noted that pathological laughter (laughter seizures; gelastic epilepsy) occurs as epileptic seizures. Pathological laughter has been classified from a neuropathological perspective as: epileptic, prodromal fourire, and motor neuron diseases (Poeck, 1969; 1985).

Gellastic epilepsy

These epileptic seizures may consist solely of laughter, but are often accompanied by generalized autonomic arousal, automatic movements, and a state of impaired consciousness (Wilson, 1924; Striano, 1999). The patient's laughter during a seizure often appears mechanical and unnatural, and while some patients feel exhilaration and pleasure with laughter attacks, others experience laughter attacks as inappropriate and do not feel positive emotions during the laughter. Laughter seizures originating in the temporal region were once said to be accompanied by a sense of joy, while those originating in the hypothalamus were not, but this claim has been questioned by reports documenting the sense of joy in some patients during seizures caused by hypothalamic seizures (Arroyo, 1993; Sturm, 2000).

The most common brain regions with pathology are reportedly the hypothalamus, frontal pole, and temporal pole. The most frequent lesion in laughing epilepsy is observed with hypothalamic melanoma, and epileptic wave activity has been reported not only by surface electrodes but also by intracerebral recordings in patients with laughing epilepsy due to hypothalamic melanoma (Munari, 1995). PET hyper-perfusion in the tumor during laughing seizures, as well as hypothalamic and pituitary hormone secretion during seizures have been reported (Arroyo, 1997). Electrical stimulation of the malignant tumor itself produces typical seizures (Kuzniecky, 1997) and surgical removal of the tumor can reduce the incidence of seizures (Nishio, 1994; Kuzniecky, 1997). The malignant tumor of hypothalamus is thus suggested to be involved in the generation of these seizures. The abnormal electrical activity caused by such tumors spreads to adjacent limbic areas and the brainstem, causing laughter attacks (Kuzniecky, 1997).

Prodromal symptoms (*fou rire prodromique*)

Prodromal cerebral ischemia (also known as '*fou rire prodromique*') is a rare condition in which inappropriate laughter occurs as the first symptom of cerebral ischemia. This laughter causes giggling and crying, followed by typical stroke symptoms such as hemiplegia and aphasia. Lesions associated with *fou rire prodromique* have been reported to include the bilateral basal cortex (Wali, 1993), left parahippocampal gyrus (Ceccaldi, 1994), left lens and caudate nuclei (Carel, 1997), and in the right middle cerebral artery supply area (Lago, 1998). Laughter in these cases may have been caused by lesions of inhibitory neurons, and these lesions are thought to produce a discharging effect on the brainstem regions that generate laughter.

Pathological laughter due to neurological disease

Inappropriate and uncontrollable smiling or laughing in several neurological disorders has been reported as 'involuntary laughter', 'pseudobulbar palsy' (Allman, 1989; Mendez, 1999), or 'sham laughter' (Martin, 2007). Neurophysiological differences between pathological and normal laughter were reported in one study, suggesting that pathological laughter results in additional contractions of the frontalis and maxillary muscles (Tanaka, 1991).

Neuroanatomy of laughter

A variety of brain lesions have been described to be associated with pathological laughing and crying syndromes, including pseudobulbar palsy, hemiplegia and biparesis with 'thalamic syndrome', and tumors of the right internal capsule, right subthalamic region, putamen, and upper cerebrum (Wilson, 1924). In a cohort of 148 consecutive patients after 'unilateral stroke', 34% of patients had post-stroke emotional incontinence (excessive or inappropriate laughing, crying, or both) and reported that damage to the lentiform capsule, basal forebrain, medial medulla, and cerebellum was more common in this subgroup (Kim, 2000). Morbid laughter is a symptom in approximately 10% of patients with multiple sclerosis and has not only been reported to increase in parallel with disease progression (Feinsteinm, 1997). It has also been observed in patients with amyotrophic lateral sclerosis, chronic progressive spinocerebellar myelopathy, and progressive supranuclear motor system degeneration. To summarize the case observations in literature to date, most of the lesions in the interneurons and cerebral bridges associated with pathological laughter are in the ventral regions of these structures, suggesting a functional separation between the structures required for the formation of pathological facial expressions from emotion-neutral facial expressions requiring the regions of the mesencephalon and cerebrum. Ventral lesions in these regions result in paralysis of spontaneously produced facial expressions, although the emotion-driven expressions are either undamaged or exaggerated. Lesions in regions of the dorsal capsular structures suppress emotional expression. For example, lesions of the basal ganglia or internal capsule may be accompanied by pathological laughter, volitional muscle paralysis, and emotional paralysis. As for lesions of the thalamus, only affective paralysis has been reported, with no reports of paralysis of the decision-making muscles, and no reports of pathological laughter or crying. Conversely, pathological laughter (but not emotional paralysis) has been associated with

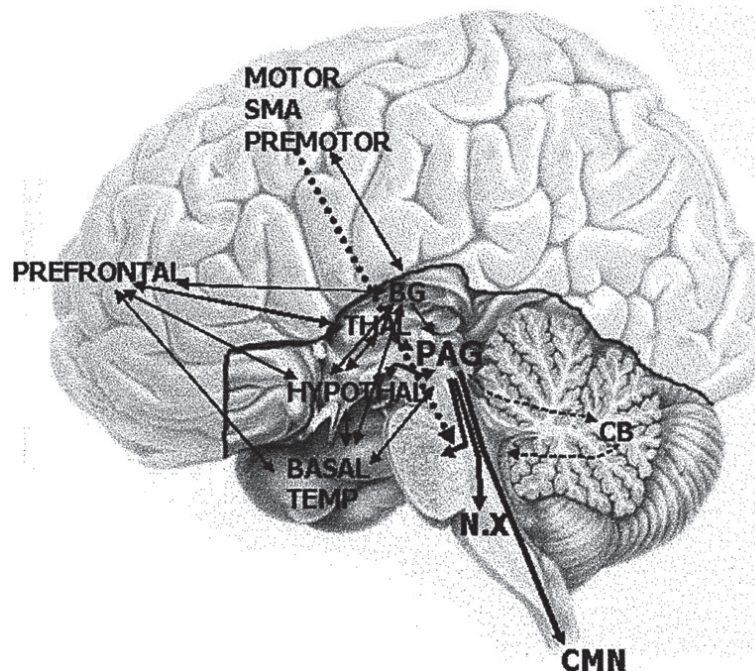
extensive frontal lobe brain lesions, cerebellar lesions, and degenerative disease of the motor cortex and pathways from the premotor cortex to the brainstem.

When we laugh (as well as when we cry), there is involvement of the muscles involved in facial expression (as well as those involved in the control of breathing and speech) (Wilson, 1924). The thalamus is not necessarily involved in the control of laughter, assuming a 'facial-breathing coordination center' presumably located in the upper cerebrum. However, various studies have suggested the involvement of the hypothalamus in the generation of emotional responses, as well as other interneurons, thalamic centers, striatum, and globus pallidus. The hypothalamus or nearby regions might be the center of laughter activity (Martin, 1950). However, the current prevailing view is that the hypothalamus is not a 'laughter center', but rather that laughter associated with lesions in this region is induced by lesions in the limbic system and its connections to palatal structures. A brain bridge 'coordination center' for laughter has been suggested (Poeck, 1969), and that study considered pathological laughter to be pure, which challenged Wilson's model

of voluntary and involuntary innervation and instead postulated brainstem centers under phasic and tonic innervation, which he termed 'coordination centers'.

To summarize the research on the neural basis of laughter, most researchers believe that there is a final common pathway for laughter that integrates facial expression, respiration, and autonomic responses in the brainstem. Dorsal midbrain lesions are thought to cause reduced facial emotional expression, whereas ventral lesions are thought to cause pathological laughter. These laughter coordination centers are both located in the dorsal region of the upper mesencephalon and are connected to the periaqueductal gray and brainstem reticular formation of the midbrain aqueduct. During healthy emotional responses (e.g., laughing, crying, frowning), the periaqueductal gray and upper reticular formation are thought to receive excitatory inputs, particularly from the prefrontal and basal temporal cortices, basal ganglia and hypothalamus.

A conceptual diagram of the neural substrate involved in the generation of laughter is shown in Figure 2. The laughter response is presumably modulated in an inhibitory manner by pathways running from



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Figure 2. Neural basis of laughter

The neural circuits involved in the production of normal and pathological laughter are shown. In the midbrain and bridge regions, fibers from the periaqueductal gray region that transmit laughter signals are located dorsally, whereas fibers from the frontal motor cortex run ventrally, presumably suppressing facial expression. BASAL TEMP; basal temporal lobe including amygdala, BG; basal ganglia, CB; cerebellum, CMN; cervical motor nuclei, HYPOTHAL; hypothalamus, MOTOR; motor cortex, N.X.; vagal nucleus, PREFRONTAL; medial and dorsolateral prefrontal cortex, PREMOTOR; motor cortex, THAL; thalamus.

the premotor cortex and motor cortex through the cerebral legs to the ventral brainstem. However, the relation between neuronal activity in this pathway and changes in emotion (e.g., joy, sadness, surprise) is not understood. While many facial expressions are voluntary, for most people it is difficult to imitate a genuine, emotionally charged smile. Willingness is needed not to produce laughter, but rather to suppress it. Thus, it is perhaps better to think of emotionally-driven genuine laughter as usually not being initiated in the motor cortex, but rather as laughter caused by the cessation of the cortical frontal inhibitory system. Some pathological laughter is caused by disturbances to this inhibitory system, and pathological laughter is thought to have a neural basis in subcortical inhibitory deficits, similar to the inhibitory deficits seen in patients with limb spasticity and bladder spasticity. Furthermore, in patients with tumors on the ventral side of the brainstem, the inhibitory pathways may be disrupted by pressure, resulting in pathological laughter.

WHAT IS HUMOR?

Humor is a complex higher cognitive-emotional process assumed to be unique to humans that refers to funny behavior that makes others laugh, but it also encompasses the mental processes involved in creating and perceiving humorous stimuli and the emotional responses involved in enjoying them.

Humor can be defined as speech or behavior that provides a pleasant stimulus to the recipient and induces spontaneous laughter. However, defining humor as a stimulus that induces laughter is insufficient, because there are various types of laughter. Defining humor and explaining its content have been unsatisfactorily attempted since ancient times, but not yet in a way that satisfies everyone.

The relationship between humor and laughter is similar to that between pain and crying. Just as we cry because of pain, we laugh because of humor, but both are followed by subjectivity and an emotional response to it, and both share the characteristic of a mixture of responses at various levels, including aspects of subjectivity, physiological responses, neural activity, objective responses, and even the implications of the experience (Damasio, 2003).

While there are operative definitions of humor and fun in individual studies, there is no consensus as to their precise meaning. The relationship between the subjective feeling of emotion (exhilaration) and its kinetic expression (laughter) has long been discussed (Damasio, 2003; Kawamori, 1969).

Whether one finds humor or amusement in certain things varies not only from person to person, but also from era to era, language to language, and culture to culture. The reality of humor is unclear. It might be a type of perception, or something produced as a result of cognitive processes, or both.

Humor permeates human society widely across regions and eras and has a role in interpersonal relationships, and many have sought to explain the significance of humor in society. The superiority theory of humor, which considers human aggression as an essential element, states that humor helps maintain social order and strengthens social bonds by allowing interpersonally inferior people to express their feelings of disagreement and disagreement in a positive manner in the form of humor. This is believed to be helpful in maintaining social order and strengthening social bonds (Martin, 2007). Tension-relief theory conceptualizes humor as a mechanism that physically and logically releases tension, and it is believed that perceiving humor and immersing oneself in laughter can help relieve pent-up stress (Wilkins, 2009). According to Freudian psychoanalysis, in the sex selection theory, humor functions as an indicator of aptitude in the selection of sexual partners, especially in providing information on the quality of mates, which is fundamental for women in judging men (Wilbur, 2011; Gervais, 2011; Gervais, 2005). The validity of any of these social functions of humor is difficult to determine, but here, it is enough to admit that humor is widely prevalent in society for these reasons.

Requirements for humor and its social significance

As Romanticism flourished in the late 18th century, many philosophers and literary scholars published reflections and definitions of humor. The German novelist Jean Paul (1763-1825) analyzed humor in terms of its relation to the real world and how it differed from parody and jokes. The German philosopher Karl Wilhelm Ferdinand Solger (1780-1819) tried to understand humor in his theory of irony. Goethe and Hegel also presented their own interpretations and views on humor. In an attempt to define humor in terms of the greatest common denominator of these considerations, humor may be about a sense of satisfaction after recognizing a slight sense of discomfort.

How humor differs from esprit or wit is widely debated (Kawamori, 1969), but a good knowledge of the language and education is clearly necessary to understand or create humor. Humor has been pointed out to not always cross borders successfully, and humor from different societies may be difficult to

understand and translate. When lacking a common culture (common understanding or assumptions), it is possible that one person's attempts to soothe a recipient by expression of humor may be especially unsuccessful. Even after translation into a different language, the humor may not be understood as humor owing to cultural nuances.

The incongruity detection and resolution theory, in which humor has two components, attempts to explain how people understand humor. The first component is the introduction of incongruity, which is caused by things that do not normally happen at the same time. The second component is resolution, in which an unexpected violation of expectations, conventions, facts, or intentions elicits cognitive arousal and involves pleasant feelings (Forabosco, 1992). To find something funny, there are two stages in the processing of humorous material (Suls, 1972). In the first, the recipient realizes that their expectations have been betrayed by the ending of the joke. The receiver thus encounters the lack of a punchline and falls into a state of dissonance. In the second stage, the receiver engages in problem solving to find a cognitive rule that harmonizes the discordant parts by means of the punchline presented following from the main part of the humor. Humor is thought to be shaped by the two stages of dissonance to convinced state. These two stages alone are perhaps insufficient to explain the difference between the perception of humor and a similar situation, i.e., the perception that a problem has been solved. A third stage should perhaps be included because it is important to feel something is funny. Potential elements of humor that are included are perceived as humorous, exhilarating, motor expressions of laughter, and uplifting. Each of these elements may have their own unique brain substrates, but it is clear that the perception of humor depends on brain functions such as attention, working memory, mental flexibility, emotional evaluation, verbal abstraction, and the sense of positive affect. Given their involvement, it is theoretically possible that at least areas of the brain associated with these processes are to some extent involved in the perception of humor.

Humor can lead to positive emotions and is thought to serve an evolutionarily important socio-emotional purpose. It has been shown to be important in building and maintaining relationships, in emotional health, and in cognitive functioning. Humor conveys ideas, attracts partners, uplifts moods, and can help people cope with trauma and stress. It can act as a natural stress antagonist and potentially strengthen relationships. As examples of the positive effects of

humor on physiology, the effects on the cardiovascular, immune, and endocrine systems have been investigated. Furthermore, humor is a prototype for positive cognitive states in humans, and therefore, it is believed to increase life satisfaction by enhancing resilience. We previously discussed the usefulness of laughter and humor rehabilitation therapy for patients with dementia, considering that laughter and humor are thought to enhance resilience in patients with dementia (Takeda, 2010).

A lesion study on the neural basis of humor

Perhaps the first attempt to relate 'humor perception' to brain regions was a report of a psychological test using funny cartoons for patients with temporal lobe epilepsy (Ferguson, 1969). The temporal lobe was identified as an essential structure for understanding humor, as relatively subtle psychological symptoms of inappropriate focus on irrelevant details, integration difficulties, concreteness, egocentrism, and paranoia impair the ability to perceive humor (Ferguson, 1969).

The perception of humor in brain-injured patients is widely reported in the literature. In a report comparing patients with brain injuries with healthy controls, those with brain injuries had lower ability in distinguishing between funny and unfunny cartoons, but there was no significant difference between patients with lesions in the left and right hemispheres in the ability to perceive humor (Gardner, 1975). However, as patients with lesions in the right hemisphere performed slightly better when there were captions, patients with lesions in the nondominant hemisphere showed impaired responses to humor (Wapner, 1981). In another study, participants were unable to discern which of several surprising endings of a joke is funny because of its consistency with the body of the joke (Brownell, 1983). In another, there were similar results between when cartoons were used and verbal jokes in understanding humor. In a study of 21 right-handed patients with a single focal brain lesion localized to the frontal (right, left, or bilateral) or non-frontal (right or left) regions, the right hemisphere was found to be not involved in the comprehension of humor (Bihle, 1986). Patients with right frontal lesions showed impaired ability to distinguish humorous from non-humorous cartoons and had fewer emotional responses (laughter, smiling). The integration of cognitive and emotional information in the right frontal lobe was said to be important for the highest evolved human cognitive functions of self-awareness and humor (Shammi, 1999).

In addition to patients with focal lesions, patients with Parkinson's disease have also been studied for the perception of humor. They could reportedly perceive the element of surprise in humorous sketches even when there was impairment of their spontaneous emotional expression, as long as their cognitive function was not impaired (Benke, 1998). Surprise is thus an important component of much of, if not all, humor. In one study, patients with extensive prefrontal lesions after herpes zoster were particularly unable to experience surprise (Brazzelli, 1994).

Neuroanatomy of humor

A review of the neural basis of humor appreciation summarized 15 years of fMRI research on the cognitive processes of humor (Vrticka, 2013). The humor stimuli discussed in the above literature can be divided into two main groups: verbal and visual. Verbal stimuli are presented in written or spoken form, and their humor content includes phonological jokes, semantic jokes, funny puns, and nonsense puns. Visual stimuli, on the other hand, can be static, such as cartoon images, or dynamic, such as short movie clips. Owing to the many types of stimuli used, humor appreciation has been shown to activate many cortical and subcortical brain regions responsible for many cognitive and emotional functions. These distinctive activation sites converge in findings that suggest two dissociable but interdependent core processes that play an important role in humor comprehension.

The cognitive component is related to the detection and resolution of dissonance and relies essentially on the activation of visual, auditory, and/or verbal and semantic knowledge areas, (especially on the left side) the inferior frontal gyrus (IFG; Brodmann area 45 (BA45)) and BA46 and BA47) and the temporal pole (TP; BA38) BA38). In the case of theory of mind tasks that require juxtaposition of mental states, understanding humor also mobilizes activity in cortical midline structures such as the medial prefrontal cortex (mPFC), posterior cingulate cortex and precuneus, superior temporal gyrus and superior temporal sulcus anterior and posterior. Incongruence may involve error detection and monitoring, and so activation of the anterior dorsal cingulate cortex (ACC) has been reported in this context. These regions include the temporal-parietal junction (TPJ; BA22, BA39, BA40) as well as the temporal-occipital-parietal junction (TOPJ; BA37, BA39, BA40). This region receives multimodal input from a variety of sensory afferents and is also known to be activated during self-related processing and theory of mind. It is also involved in the detection

of unexpected stimuli related to behavior and has increased coupling with the ventral prefrontal cortex, which is associated with attention and decision making. The TOPJ may therefore be involved in the detection and resolution of incongruence. An emotional component is also involved in humor perception; it mobilizes the insular cortex, ventral ACC, and supplementary motor area (SMA), but is primarily associated with increased activity in mesocortical limbic dopaminergic regions (i.e., ventral tegmental area, substantia nigra, nucleus accumbens, ventral striatum, ventral mPFC).

Blood oxygenation level-dependent (BOLD) signaling in mesocortical limbic dopaminergic areas is known to increase during various reward-related responses, and such activation has also been reported by correlation analysis with subjective enjoyment ratings, a process of humor comprehension, also called humor elaboration. It is understood to represent a positive sense of enjoyment or reward, but the exact nature of the positivity associated with humor has not yet been fully elucidated. Elevated subjective ratings of amusement also correlate with BOLD signal changes during humor processing in cognitive areas consisting of TPJ, TP, mPFC, ACC, posterior cingulate cortex, and precuneus, suggesting that humor appreciation is not limited to areas associated with basic reward sensations associated with dopaminergic signaling and humor recognition is not restricted to areas associated with dopaminergic signaling and related basic reward sensation. Related to this idea, most neuroimaging studies of humor recognition have also shown that it is associated with activation of the amygdala. The human amygdala is known to be involved in reward-related mechanisms, and its functional profile is understood to resemble a relevance detector. The amygdala plays an important role in selecting the most relevant inputs to goals and intentions from the diverse streams of information that are constantly coming in.

Summarizing the above findings, we can conclude the following about the neural basis of humor comprehension. Humor is a person's cognition, communication and interaction that has many potential beneficial effects on personal, psychological and physical well-being, and it positively influences social and collective processes. On a functional neuroanatomical basis, it is not surprising that humor perception mobilizes a wide range of brain regions, which exhibit different activation depending on the style of stimulus and task requirements that elicit humor, but all of these subsidiary mechanisms underlying humor per-

ception are related to the detection and resolution of incongruence (cognitive component) and the pleasant or reward sensations (affective component). The cognitive component relies primarily on TOPJ activity, whereas the affective component appears to involve the mesocortical limbic dopaminergic pathway and the amygdala.

Information processing of humor

Neuroimaging studies on humor perception have reported the role of the prefrontal cortex (especially the right side) and anterior cingulate gyrus in the processing processes of detecting unexpected events during learning (Viticka, 2013), perception of unnatural colored objects (Zeki, 1998), and discrepancies between vision and tactile perception (Fink, 1999). The following is a summary of the findings.

The detection and resolution of discrepancies occur in rapid temporal succession (virtually simultaneously), so current fMRI methods have insufficient temporal resolution to separate them. EEG and magnetoencephalography investigations may therefore be better suited to address this issue. In a study of cortical electrical activity related to humor information processing, event-related potentials (ERPs) revealed a peak at 300 ms after hearing a joke punchline, followed by an overall depolarization ~100 ms after this (Derks, 1997). These two waves are suggested to correspond to a two-stage cognitive model of humor processing (Forabosco, 1992; Suls, 1972). Mood may influence humor processing, with positive moods showing greater differences in ERPs between jokes that produced laughter and those that did not, compared to negative moods. However, a more recent study using ERPs failed to distinguish between the element of surprise and the subsequent communal phase when healthy subjects read a sentence and judged whether the last word was a joke or not (Coulson, 2001).

A recent study used functional MRI to show regions of cerebral activity dependent on blood oxygenation levels in healthy subjects listening to jokes (Ozawa, 2000). The subjects were then asked to rank how interesting or difficult to understand they found each text. Consistent with the linguistic nature of the task, activity in Wernicke's area and the both lateral temporal gyrus was observed by fMRI. Meanwhile, the texts that subjects rated as interesting caused activation in Broca's area and the middle frontal gyrus (possibly corresponding to syntactic processing and auditory working memory), and those rated as difficult to understand. In one study, 14 subjects

were presented with two types of jokes: phonological jokes (puns) and semantic jokes (humor dependent on factors other than simple language play) (Goel, 2000; Goel, 2001). Subjects reviewed the jokes and rated them on a scale of funniness. Cortical activation during the pun was found in the left posterior middle temporal gyrus and left inferior frontal gyrus, whereas activation during the semantic joke was found in the left posterior middle temporal gyrus, left posterior inferior temporal gyrus, right posterior middle temporal gyrus, and cerebellum. Brain activity in the medial ventral prefrontal cortex was consistent with subjects' ratings of how funny the joke was after the scan and may be related to their emotional evaluation of humor.

In both studies, the perception of humor (due to jokes) was associated with blood oxygenation level-dependent activity in the temporal and left frontal regions. However, the two studies were not perfectly matched in terms of activity areas, with the second study reporting activity areas not reported in the first study. Neither study controlled for confounding variables such as attention or emotional facial reactions, so the assumption that humor was the cause of the observed activation may be incorrect.

PET was used in one study to examine subjects' facial responses to humorous film clips (Iwase, 2002). Humor-induced smiles or laughter (measured by electromyography of facial muscles) showed bilateral selective increases in regional cerebral blood flow (rCBF) in the subjects' supplementary motor area and left putamen compared to baseline. Humorous laughter/smiling, in contrast to spontaneous smiling, was associated with increased rCBF in visual association areas, the left prefrontal cortex, the left anosmia, the orbitofrontal cortex and the medial prefrontal cortex. In contrast, spontaneous smiling was associated with increased rCBF in the facial areas of the left primary motor cortex and bilateral supplementary motor area compared to humorous smiling. However, in this paradigm, it was not possible to distinguish between rCBF related to humor and rCBF related to behavioral responses.

In a study of facial responses to pictures of emotionally expressive faces, activation of the bilateral basal temporal cortex, including the amygdala, was observed when subjects produced a smile in response to a picture of a smiling face (Wild, 2003).

In a report examining the neural circuits involved in humor creation (Amir, 2016), professional and amateur improvisational comedians were shown pictures of cartoon and they were asked to create a humorous or banal caption for each picture. Comparison of

fMRI during captioning revealed that the more experienced comedians showed decreased activation in the striatum and medial prefrontal cortex (mPFC) and increased activation in the temporal medial prefrontal cortex. Less experienced comedians had greater activation in the mPFC, reflecting deliberate exploration of the temporal medial prefrontal cortex association space. In contrast, professionals showed less reliance on top-down guided exploration and a tendency to utilize the fruits of spontaneous associations. Based on this finding, humor creation is characterized by activation of a network of regions including the mPFC, striatum, and temporal cortex. mPFC activity was observed to be greater during humor creation (compared to creation of mediocre captions), but its activity decreased with professional experience. This suggested that while the mPFC may help to direct the exploration of associative space occurring in the temporal regions, such an intervention was less necessary for experienced comedians, who reap more of the fruits of spontaneous associations.

LAUGHTER AND HEALTH

Here, we define laughter as ‘a psychophysiological response to humor or other pleasant stimuli’ (Stiwi, 2022). Laughter is associated with external or internal stimuli (positive emotions, pleasant thoughts, self-induced laughter), but humor and laughter are distinct and do not necessarily appear together (Takeda, 2024a). Natural laughter is elicited by external humorous stimuli or positive emotions, whereas simulated laughter is self-induced, intentional, and not elicited by external stimuli or positive emotions. Stimulated laughter occurs as a response to an external stimulus, such as tickling. Induced laughter can be caused by the use of certain drugs or substances (e.g., alcohol or ‘laughing gas’), and pathological laughter can be a symptom of certain neurological or psychiatric disorders (Mora-Ripoll, 2011).

Both natural and simulated laughter are frequently studied in the context of health interventions. Interventions using natural laughter include exercises associated with humor, such as watching funny videos or interacting with clowns. Interventions related to laughter that do not use humor include clapping, dancing, laughing, and vocalizing laughter-like sounds, but these interventions are usually incorporated into a broader set of exercises that also include breathing and relaxation techniques and facial and body exercises (Mora-Ripoll, 2013). Laughter yoga is a frequently applied intervention, which combines

breathing exercises with genuine or simulated laughter or humor (van der Wa, 2019; Zhao, 2019; Demir, 2020). The characteristics of different reported laughter interventions is shown in Table 3.

Positive effects of these laughter interventions have been reported on the muscular, cardiovascular, respiratory, endocrine, immune, and central nervous systems. Psychological benefits in terms of cognitive function, social functioning, mental health, and quality of life have also been reported in many cases (Table 4). Several meta-analyses have summarized the evidence for the effectiveness of humor and laughter interventions in various patient populations and in healthy individuals. Another meta-analysis of seven studies involving 421 participants found that the effect of laughter therapy on quality of life was small and did not reach significance (Demir Doğan, 2020). Furthermore, in another meta-analysis of 10 studies of 814 participants that expanded the analysis, laughter and humor interventions significantly reduced depression and anxiety as well as improved sleep quality (Hwang, 2019). The duration of the laughter therapy intervention is important, with long-term laughter interventions having a stronger impact on depression than short-term interventions (Zhao, 2019). The most comprehensive meta-analysis evaluation to date examines the effectiveness of laughter therapy for a variety of populations and outcomes and includes nine randomized and 20 quasi-randomized studies (van der Wa, 2019), which report that laughter-induced interventions have depression and significant effects on anxiety, and interestingly, made-up laughter has a larger effect size than spontaneous, humorous laughter.

Interventions that induce laughter may have a positive impact on patients with physical or mental health problems. Patients may benefit from these interventions through reduced mood, happiness, quality of life, or reduction in anxiety, depression, stress, pain, and fatigue. Reports of adverse events are rare, with only one study reporting negative effects from laughter interventions. The made-up laughter intervention has the greatest positive effect on mental health among physical, physiological, psychological, and social health. Furthermore, group laughter interventions appear to be more effective than single interventions. However, given the limited internal validity of the studies included in the meta-analysis and considerable heterogeneity across studies, future research should aim to balance the benefits and harms of laughter-inducing interventions by applying methods with low risk of bias (van der Wa, 2019).

Table 3. Laughter intervention therapy in practice

Laughter Yoga	Laughter therapy	Clown	Passive stimuli
<ul style="list-style-type: none"> • Commonly following a manual by Dr. Kataria • Laughter exercises (e.g., greeting laughter, lion laughter, milkshake laughter, cell phone laughter, closed mouth laughter) • Laughter meditation (focusing on the experience of laughter and the associated bodily sensations) • Handclapping or body movement with chanting (“hoho, hahaha”) • Breathing exercises • Relaxation exercises • Positive affirmations (e.g., “I am the happiest person in the world!”) 	<ul style="list-style-type: none"> • Usually consisting of 3 phases with varying content (e.g.): 1) Warm-up • Information about benefits of laughter • Simultaneously singing • Humming, hugging, clapping 2) Main activities • Practicing various forms of simulated laughter • Reciting funny poetry and prose or playing funny games to foster spontaneous laughter 3) Cool-down • Sharing of feelings • Relaxation/meditation with music • Stretching exercises 	<ul style="list-style-type: none"> • Clown with costumes and make up • Interaction with patients using various methods (e.g., balloons, puppets, word games, magic tricks, dice tricks, jokes etc.) • Combination of humor (bringing fun to people and making people laugh) and love (treating patients with compassion and generosity, getting close to patients) 	<ul style="list-style-type: none"> • Watching funny videos • Watching comedian live-performances • Listening to an humorous audiotape

Table 4. Health benefits of laughter intervention

health index	effect
muscle relaxation	Muscle relaxation occurs after strong laughter and the golden tonus decreases (26,27).
Urinary epinephrine and norepinephrine levels	Humor video viewing causes activation of the sympathetic nervous system (28)
Galvani skin response (GSR) and blood pressure	Humor shows an increase in GSR response but not in blood pressure. This indicates that humor has a buffering effect on blood pressure as well as an enhancement of the diurnal nervous system (29)
Heart rate and respiratory rate	Laughter causes an increase in heart rate and an increase in respiratory rate paired with an image pair of oxygen consumption (39).
Anxiety, heart rate and blood pressure	Humor reduces self-reported anxiety but does not affect objective measures of anxiety (heart rate and blood pressure).(31) Blood pressure does not increase.
relaxation	Humor shows a relaxing effect in college students with high internal tension (32)
Various hormones	Humor decreases serum cortisol and DOPAC levels. Serum prolactin, beta-endorphin, epinephrine, and norepinephrine are not altered (5).
SIgA	Humor increases SIgA (6,11)
NK cell activity	Humor has been reported to increase NK activity (22) and not to alter it (21)

Simulated laughter and health benefits

In a paper on the health effects of simulated laughter, laughter was classified into genuine or spontaneous laughter, simulated laughter, induced laughter, and pathological laughter (Mora-Ripoll, 2011). Spontaneous laughter is the so-called Duchenne laughter caused by positive emotions in response to humor or other stimuli. Simulated laughter is self-induced laughter that does not require external stimuli such as humor and is not related to positive emotions. Induced laughter is laughter provoked by physical stimuli such as tickling. Pathological laughter is that caused by central nervous system disorders such as epilepsy, cerebrovascular disorders, and neurodegenerative diseases. Laughter that has been studied with attention to its effects on health is mainly spontaneous laughter and simulated laughter (Table 5).

Health promotion methods involving laughter include: laughter yoga (exercises incorporating yoga breathing techniques with laughter), exercise programs (aerobic exercises and breathing activities while laughing), playful behavior (play to relieve tension), emotional well-being (pantomiming movements

while laughing), and special programs (brain exercises while laughing, dancing and singing, exercises while talking, floor exercises). The most common of these is probably laughter yoga, a program that combines yoga breathing techniques with 'ha-ha-ha' or 'ho-ho-ho' vocalizations, and there are many reports of its practice.

Health-enhancing effects of purely simulated laughter

We would like to study whether making facial expressions of laughter while looking in the mirror at oneself (without combining it with yoga or gymnastics) has the same health benefits as laughter (Takeda, 2024b).

As previously mentioned, the effects of laughter on mental health have been reported as a health benefit of laughter. A larger effect size has been reported for laughter when comparing natural laughter to simulated laughter, but most laughter interventions are the result of laughter yoga, an intervention that combines laughter, breathing, and exercise. To evaluate the effects of purely simulated laughter, it is necessary

Table 5. Characteristic comparison of spontaneous laughter and simulated laughter

Comparison of spontaneous laughter (spontaneous laughter) and simulated laughter (simulated laughter) characteristics		
	Spontaneous laughter (spontaneous laughter)	(simulated laughter) (simulated laughter)
Expression of pure positive emotion	It's always there.	not certain that there is
Humor involvement	there are many cases	very little
Relationships with others	Laughing at others	Laugh with others
Proactive thinking	Necessary in many cases	Almost unnecessary
Duchenne type expression	typical	Only if you make an effort
Physical Exercise with	accompanying motion	voluntary movement
Triggered by free will	nashi (Pyrus pyrifolia, esp. var. culta)	ant
Stimulus causing	Many are due to external stimuli.	No external stimuli.
Contagion to others	ant	often
Adjustment of strength and duration	I can't do most of it.	possible
Vowel/Consonant Ratio	Almost one to one	Undecided
vocalization	Ha ha ha, ho-ho-ho, etc.	Undecided
Health Benefits	Yes (numerous studies exist)	Probably yes (few studies)
Appropriate laughter embodiment	group (usu. of people)	Alone or in a group
Examples of Induction Methods	Play, clowning, disguise, dancing, singing, funny things, humor, surprise, release of tension, pleasant emotions	Laughter yoga, exercise, laughter exercises, practice laughter, one-person laughter

Modified from Mora-Ripoll, Complem Therap Med 19, 170-177, 2011

to distinguish and examine factors such as positive emotions elicited by humor and activation of the respiratory and cardiovascular systems by yoga and gymnastics.

Physiological effects

Spontaneous laughter is known to enhance endorphin secretion and endorphins have the effect of elevating mood, inducing positive affect and thus reducing stress. Considering that smiling promotes interpersonal interaction in interpersonal relationships, a similar effect may be expected from smiling and looking at one's own face in the mirror. However, the expression of a person's own smiling face is only their own expression and this does not necessarily reflect their relationships with others.

Laughter is known to decrease cortisol in saliva and urine. Cortisol is generally secreted when the sympathetic nervous system becomes dominant as a stress response. Smiling reduces stress, and when the parasympathetic nervous system becomes dominant, there is decrease in the level of the stress hormone cortisol. When the parasympathetic nervous system becomes predominant through laughter, it becomes easier to relax, the stress is reduced, and the level of cortisol may decrease.

Psychological effects

The relationship between laughter, humor, and positive effect is complex. Although it is generally assumed that spontaneous laughter is a unidirectional process in which a humor stimulus elicits a positive emotional response that results in spontaneous laughter, it is possible that the transmission of laughter to others or the observation of laughter and smiling faces can elicit positive emotional responses. Considering the bidirectional effects, positive emotional responses may be elicited by simulating a smile. By making a positive facial expression, the brain is more likely to feel positive emotions, and smiling can be expected to actually improve one's mood. Smiling at oneself may also help one to perceive oneself positively, and smiling while looking in the mirror may help to increase one's self-esteem and self-confidence.

Social effects

Smiling has the effect of making it easier to relate to others and facilitate communication. When we smile, people around us are also more likely to relax, which may have the social effect of facilitating mutual relationships with others.

Practice methods

Given the positive emotional response that the smiling face possesses, which sends positive feedback to the brain, it may be effective to practice smiling in front of a mirror for a few minutes each day. Consciously smiling in daily life may also be effective, especially when feeling stressed or depressed, consciously smiling may improve one's mood.

Comparison with laughter

Laughter often has stronger physiological effects than smiling, especially in improving cardiorespiratory function and in releasing muscle tension. However, smiling may also have sufficient positive effects. Given its ease of practice, smiling may actually be more useful than laughing. Although there are not always situations that naturally induce laughter, simulated smiling is an easy way to practice it on a daily basis. In this light, smiling while looking in the mirror can be considered a beneficial habit that, like laughter, contributes to improved health and mood.

CONCLUSION

Spontaneous laughter is a very human behavior elicited by humorous stimuli. There are many types of laughter other than spontaneous laughter, each of which is modulated by the cerebral cortex but activated by the laughter center in the upper dorsal mesencephalic region. Neural activity in the upper dorsal mesencephalic region is connected to the periaqueductal gray and reticular formation of the midbrain aqueduct, and is expressed as physical responses, mainly facial muscle activity. Although the periaqueductal gray and upper reticular formation receive excitatory inputs from the prefrontal cortex, the basal temporal cortex, the basal ganglia, and the hypothalamus in the emotional response of healthy laughter, such inputs to these laughing centers are thought to be scarce in simulated laughter. However, we can expect similar effects of physical reactions mediated by the periaqueductal gray, reticular formation, and pyramidal tract nervous system in the upper dorsal area of the mesencephalon and beyond in simulated laughter as compared to natural laughter. We can therefore expect the same or greater health benefits from simulated laughter as from natural laughter.

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