In Search of the Cerebral Funny Bone: Brain Deficits and Their Neuropsychological Correlates with Humor

Trauma or other brain deficits can impact the patient’s ability to recognize and respond to humor.

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Case Presentation
Amanda is a 34-year-old female. One year prior to her annual physical with her primary care doctor, she was involved in a car accident where she was hit from behind. The right side of her head struck the steering wheel, causing her to chip two teeth, bruise her shoulder, and sustain a loss of consciousness for three minutes. She was taken to the hospital where she was released after one night of observation. A CT scan revealed a mild concussion. Upon her explaining the details of the accident, the physician asked about residual symptoms. Amanda said that she had been experiencing symptoms of lack of attention, slight memory deficits, difficulty following directions and difficulty with social interactions. But it was her husband who noticed there was something much more specific—and potentially very awkward—with her social problems. He said that over the past year, Amanda seemed to have lost her sense of humor. When presented with a joke that others found funny, Amanda would not laugh. When her husband asked her why she had not laughed, Amanda said she had not understood the joke or that she had not realized the interaction was meant to be a joke.

The physician referred Amanda to a neuropsychologist for neuropsychological testing, where she completed a Wechsler Adult Intelligence Scale 3 (WAIS-III), Wechler Memory Scale 3 (WMS-III), Halstead-Reitan Neuropsychological Test Battery, Penn’s Humor Appreciation Test (PHAT) and the Joke and Story Completion Test (JSCT). Amanda performed in the average range on the Verbal Index of the WAIS-III and in the low average range on the Performance Index. Amanda performed in the below average range on all indices of the WMS-III. The Halstead-Reitan Neuropsychological Battery revealed moderate impairment, suggesting damage in the right hemisphere. Amanda’s performance on the PHAT and JSCT revealed difficulty with humor appreciation and humor comprehension. For example, Amanda had dif-
ficulty understanding the humorous aspect of the jokes and cartoons presented to her, and at times had difficulty distinguishing funny from unfunny jokes and cartoons. Additionally, she had difficulty with the coherence of the joke and often chose a more logical explanation for the cartoons rather than the funny or surprise ending on the JSCT. The neuropsychologist concluded that Amanda had sustained right hemisphere damage, interfering with her humor abilities.

Humor is a ubiquitous phenomenon. One purpose of the present article is to determine if humor is purely psychological and emotional or if there is a neurological or anatomical aspect to this phenomenon. It appears, as is discussed in detail below, that much of humor is encompassed by neurological mechanisms. Humor and its various aspects activate specific areas of the brain. Additionally, certain types of stimuli activate specific areas of the brain, which allows an individual to perceive and experience humor. Although one does receive pleasure from humor, this appears to occur from the dopamine reward centers of the brain, leading one to believe that humor is primarily neurologically based.

Humor Theories
Researchers have postulated various theories relating to humor. One predominant theory, the Incongruity Theory, proposes that humor occurs in two separate stages. During the first stage, the listener holds expectations of the joke being disconfirmed upon reaching the punch-line. Throughout the second stage, the listener of the humorous stimuli undergoes a problem solving task to resolve the incongruity between the punch-line of the joke and the expectation created by the joke. This is also known as the surprise element of the joke. For full comprehension and appreciation of the joke, both of these stages must be fully resolved. Other researchers propose an addition to this theory: in order to find a joke humorous, one needs to experience a “flash of insight” or perceive how a new interpretation of the same facts can occur simultaneously with one’s prior experience and subsequently incorporate this new anomalous ending. This incongruity theory can be applied to sarcasm, irony and deceptive praise. Deceptive praise occurs when one gives false praise to another, with the intention of the listener falsely believing this praise to be true. Although these need not be humorous, they still require an individual to complete each stage in order to understand the message being sent to the listener. The false alarm theory postulates that evolutionarily, humorous stimuli leading to laughter were used to announce that one has discovered a false alarm. Specifically, laughter served the purpose of acknowledging that one is allowed to feel good again and relieve the tension of worrying that danger is present.

Components of Humor
Throughout the past few decades, researchers have divided humor into cognitive and affective elements. The cognitive element, known as humor detection, entails comprehending or understanding the humorous stimuli presented. During this stage, the listener must be able to grasp and understand the differences or incongruities between the punch line and one’s prior experience. The affective element, known as humor appreciation, consists of enjoying the joke, where the listener is able to experience physical and emotional responses from the humor. Researchers suggest that the left hemisphere is responsible for integrating information into a coherent manner to understand a joke, whereas the right hemisphere is responsible for the emotional processing associated with the surprise element of humor.
Humor appreciation. Researchers have proposed that humor appreciation is a dual part process involving detection of humor as defined above, as well as a reinterpretation of the story based on different meanings.4 Humor appreciation requires interpretation of current information based on one’s past experience.20 Deficits in this area appear to be related to impairments in active response inhibition, selective attention, sustained attention, vigilance, and phonological word fluency, which is associated with information processing problems and frontal lobe impairment.3

The right anterior frontal lobe plays a large role in humor appreciation, utilizing the ability to interpret, organize and integrate information.11,20 Additionally, areas of the prefrontal cortex, cerebellum lead to amusement derived from a joke.2,10,18,25 This activates affective and emotional responsiveness, important for novel problem solving and narrative communication.20 Furthermore, areas of the temporal and occipital lobes become engaged, indicating their importance for language tasks such as retrieval and appraisal of relevant semantic knowledge, bringing expectations to the forefront.13,14

Motivation and reward are highly associated with humor enjoyment and laughter. The dopamine system appears to be highly involved in rewarding the brain. The two primary areas in the brain responsible for an activated dopamine system are the substantia nigra and the medial ventral tegmental area in the midbrain.10,21 The experience of reward and emotions while watching humorous cartoons activates the nucleus accumbens, amygdala and hypothalamus.17 This may lead to the positive emotions of humor. Similarly, Taber, et al.21 noted activation in the insular cortex and amygdala during visceral and emotional aspects of humor appreciation. The basal temporal activation is related to emotional components of one’s reaction to humor, as well as to the facial expression of emotion.26 The right frontal lobes have also been implicated in emotional responsiveness.20

Humor comprehension. In order to comprehend humor, one must possess skills such as language processing, reasoning, mental flexibility and working memory.4 Additionally, one must be able to perceive non-literal language and comprehend social pragmatics. Humor comprehension activates areas in the temporal and occipital lobes, which are important for semantic processing of humor stimuli. Areas of the frontal, temporal, parietal, and prefrontal cortex are involved in the cognitive humor processing or incongruity resolution.18 As more information is integrated, the joke will make more sense. In addition, more activation will be found in the temporal-parietal junction, which contributes to generating, testing and correcting internal predictions about external sensory events.18

Humor response. Once detected and comprehended, humor activates the subcortical structures including the ventral tegmental areas, the nucleus accumbens, and the amygdala, which are all implicated in the dopaminergic reward system.13 When activation extends to the cingulate cortex, it implicates reward based decision making, attention allocation and laughter.13 Humor induced smiling and expressive laughing activated the supplementary motor areas and areas of the forebrain.13,25 Additionally, the amygdala also activates in response to the surprise element of the joke.14

Deficits in Humor
Right hemisphere damage (RHD). The most marked deficits in humor are found in those with damage to the right frontal lobes.4 Individuals with RHD tend to have deficits in understanding cartoons and verbal jokes.4 RHD patients tend to have difficulty understanding the overall message of a joke.11 These individuals are able to recognize a two part joke, but have difficulty with the coherence of the joke.11 These individuals appear to be more sensitive to the surprise element of jokes.5,13 Therefore, the right hemisphere is important for maintaining meaning and coherence across a narrative.12 Additionally, these patients show a decreased ability to offer logical explanations of cartoon humor.20 For verbal humor tasks, those with right frontal brain damage were impaired, whereas those with left hemisphere damage were not.20

Individuals with RHD appreciate humor less than others and have a lesser spontaneous emotional
response to humor, as there tends to be a dissociation between cognitive and affective responses. At times, these patients appear to understand jokes and rate jokes as funny, but do not respond with a smile or laughter. Similarly, those with right frontal lobe impairments showed greater deficits on tasks of humor appreciation, and were unable to distinguish funny stimuli from not funny stimuli.

Researchers have found that errors made by patients with RHD are caused by visuo-perceptive and cognitive deficits over and above any affective deficits from damage to the right hemisphere. This leads to impairments in understanding humor. Additionally, these individuals have deficits in theory of mind, as the right hemisphere is important for social cognition. Specifically, those with RHD have difficulty understanding communicative intention. In other words, these individuals have difficulty comprehending the intended or implicit meaning from the communicated message.

**Left hemisphere damage (LHD).** Those with LHD tend to have normal levels of humor comprehension, with very few impairments. Those with LHD show some impairment in sensitivity to the surprise element of humor. Specifically, those with LHD tend to prefer punchlines that are coherent with the story but not surprising. This shows that the left hemisphere is important in appreciating the surprise aspect of humor. When LHD patients are shown captionless cartoons, they may be impaired in detecting the incongruity in the story. For nonverbal cartoons, all brain damaged individuals were impaired in the comprehension of humor except for those with left posterior damage.

**Language disorders.** Children and adolescents with language and nonverbal learning disorders tend to have difficulty identifying a language incongruity, developing a resolution and explaining this resolution, which holds consequences for comprehending linguistic humor. This appears to be related to poor social perception, as opposed to visual spatial perception deficits. Additionally, these children performed more poorly on humor tasks regardless of verbal ability, due to deficits in humor comprehension.

**Head injuries.** Researchers have found that understanding humor relies on intact cognitive and communication skills. Adolescents with head injuries were found to perform more poorly on interpretation and comprehension of linguistic humor, as well as language ability. Deficits in literal language include problems conveying the flow of information, difficulty understanding ambiguous statements, inability to understand social scripts, and difficulty producing speech acts. Specifically, children with closed head injuries tend to have semantic and pragmatic difficulties with language, such as trouble understanding and eliciting literal and nonliteral statements.

These children also exhibit difficulties in non-literal language. “They fail to understand idiomatic, figurative language in which what is said is not literally what is meant and have difficulty understanding linguistic humor and intentionality.” These children fail to understand and make inferences during a story. Likewise, children with closed head injuries have more difficulty understanding one’s intentions and understanding irony and deception. Even a mild closed head injury may lead a child to poor comprehension of irony or deception. Working memory is also involved in processing and understanding humor. For example, one may need to be able to compare other endings and link them to the joke to understand why the correct punchline is funny.

Additionally, those with head injuries tend to perform more poorly when trying to distinguish something funny from something not funny. However, there appears to be no differences in right or left hemisphere damage in one’s overall ability to perceive humor.

**Pathological laughter.** Various types of disorders can cause pathological laughter. Gelastic Epilepsy is a type of seizure in which laughter is the primary symptom. At times, these individuals may also experience general autonomic arousal and automatisms of movement. The hypothalamus, primarily related to hypothalamic hamartomas, as well as the...
frontal and temporal lobes are implicated in these difficulties. Another condition that may cause pathological laughter is Four rire prodromique in which inappropriate laughter occurs as the first symptoms of cerebral ischemia. Subsequently, the individuals acquire the symptoms of a typical stroke, such as aphasia. Lesions associated with this ailment may be found in the brainstem, parahippocampus, thalamus, internal capsule, basal ganglia, and lenticular areas. Researchers believe that laughter in this case may be caused by lesions of inhibitory neurons. Similarly, pathological laughter is also associated with brain lesions in many areas, such as the frontal cortex, the pyramidal tracts, midbrain and brainstem.

**Autism.** Researchers have found similarities between individuals with autism and individuals with frontal lobe damage. They both often tend to be very concrete and literal, having difficulty with figurative, non-literal or double meaning language. They often have difficulty understanding humor due to impairment in verbal communication. Lack of understanding of nonverbal gestures may also account for lack of understanding of nonverbal humorous stimuli. In order to comprehend humor, one must be able to communicate effectively. Also, verbal abstraction ability and shifting of mental set is associated with appreciation of verbal humor. For example, adolescents with autism perform more poorly on comprehension of humorous materials, especially as the level of abstraction increases. Researchers hypothesized that this is due to an impairment in cognitive flexibility.

Additionally, theory of mind has been shown to be lateralized to the right hemisphere. Therefore, those with right hemisphere damage and autism tend to have difficulty with theory of mind, as the right hemisphere is needed for activation of representational sets and integration of meaning as well as episodic memory. Theory of mind is also associated with executive functions such as the ability to hold information in one’s mind. This is needed to appreciate and comprehend humor.

Adolescents with a language disorder tend to be less able to use context to understand implied meaning than those without a language disorder. Those with Asperger’s syndrome do not perform as well as other children on tasks requiring interpretation of ironic jokes. These individuals were more likely to believe that the individual in the story was lying rather than telling a joke. When asked to comprehend humorous material, these individuals exhibited an impairment in cognitive flexibility, leading to the conclusion that these adolescents had difficulty with surprise and coherence in humor.

**Assessing Humor Deficits**

Although not abundant, scales have been created to measure humor. For example, the Penn’s Humor Appreciation Test (PHAT) measures one’s ability to detect and comprehend anomalous information and the level to which one perceives this information as humorous. The Humor Orientation Scale measures one’s ability to produce humor and make others laugh. Another scale, the Multidimensional Sense of Humor Scale, measures humor creativity, uses of coping humor, appreciation of humorous people and appreciation of humor. Humor scales can be utilized along with neuropsychological assessment measures to detect neuropsychological deficits. As certain areas of the brain must be functional and intact in order to perceive the final outcome as humorous, if one performs poorly on a humor measure, this may indicate that the individual has a neuropsychological deficit. Follow-up assessments with neuropsychological assessments may corroborate these findings. For example, if an individual was found to have difficulty with the coherence of jokes, or difficulty with humor appreciation, neuropsychological assessments, such as the Halstead-Reitan Neuropsychological Test Battery could be used to confirm or disconfirm right hemisphere deficits.

Humor scales and neuropsychological assessment measures may also be correlated. For instance, Bozikas, et al. found that for individuals with schizophrenia, performance on the PHAT Humor scale significantly correlated with scores on the Penn’s Continuous Performance Test (PCPT), the Stroop Color-Word Test, the digit span forward and back-
ward, spatial span forward and backward, the phonological subscale of the Greek Verbal Fluency Test, the Rey Osterrieth Complex Figure Test (ROCFT) copy condition, the Hooper Visual Organizational Test, and the Trail Making Test part A. There were no significant correlations found between performance on the PHAT and the design fluency test part A and B, Trail Making Test part B, ROCFT immediate recall, delayed recall and recognition, WLLT, Wisconsin card sort (WCST) perseverative errors or categories completed and the Greek Verbal Fluency Test semantic subscales. After bonferroni correction, the only associations between scores on the PHAT and performance on the PCPT, Stroop Color-Word Test and the phonological subscale of the Greek Verbal Fluency Test remained significant.

Conclusion and Implications
As previously discussed, various neurological mechanisms account for detection, comprehension, and appreciation of humor. In order for one to appreciate and enjoy humor, one must possess fully functioning areas of the brain. If a specific area is not functioning correctly, one of these steps may be missed and the person may not appreciate the humor. Additionally, if an area of the brain is damaged, certain stimuli may not activate those areas of the brain necessary to appreciate humor.

This holds implications for the physician. Humor may be an interesting and important area for the physician to assess. Although there are limited formal measures to assess for humor deficits (the aforementioned scales), the physician may assess for one’s general changes in sense of humor, comprehension or appreciation of humor. In this way, the physician may become aware of subtle brain damage that they otherwise may not have discovered. If the physician discovers a humor deficit in addition to cognitive difficulties in a patient, this may indicate brain impairment. This may be corroborated with neuropsychological assessment, which can confirm and more specifically pinpoint the brain impairment.

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