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Neuro- physiologic imaging in the context of traditional theories of human motivation

Rajan Masih[1], Taylor Titus[2], Lena Yeater[3], Barbra Masih[4], Paige Mathias[5], Michael Landis[6], Christian Landis[7], Maddy Brewer[8]

[1] MD, MPH, FRSPH, FICA, Department of Substance Use Prevention, Potomac Highlands Mental Health Guild, West Virginia, United States

[2] MA, Department of Substance Use Counseling, Potomac Highlands Mental Health Guild, West Virginia, United States

[3] PA-C, Department of Psychiatry, Potomac Highlands Mental Health Guild, West Virginia, United States

[4] MS, LPC, CRC, AADC, Department of Substance Use Prevention, Potomac Highlands Mental Health Guild, West Virginia, United States

[5] MPA, PS-II, Department of Substance Use Prevention, Potomac Highlands Mental Health Guild, West Virginia, United States

[6] MBA, AADC, Department of Substance Use Counseling, Potomac Highlands Mental Health Guild, West Virginia, United States

[7] FAADP, Research Assistant, Department of Psychiatry, Potomac Highlands Mental Health Guild, West Virginia, United States

[8] BA, Research Assistant, Department of Substance Use Prevention, Potomac Highlands Mental Health Guild, West Virginia, United States

Abstract

Theories of motivation have been proposed by scholars since the beginning of the 20th century. In recent decades neuroscientists have attempted to find similar physiologic drivers of human motivation (at a cellular and molecular level) to attempt to describe what causes humans to behave in goal-directed activity. Newer non-invasive neuroimaging technologies such as Single Photon Emission CT Scanning (SPECT), Functional Magnetic Resonance Imaging (f-MRI), and Positron Emission Tomography (PET) have been adopted and implemented to study the anatomic regions of the brain involved in motivation related neural activity, and to image the neurotransmitters and their receptors activated during cognitive motivational goal-directed activity. Theories of human motivation proposed by early pioneers in the field are, indeed, more than just constructs, and can be supported, validated, and reproduced through newer brain imaging technologies such as PET scanning, SPECT and f-MRI.

Keywords: human motivation, theories, neuro-imaging, correlation

Introduction

Motivation Defined

Simpson and Balsam (2016) [22] have defined motivation as, “the energizing of behavior in pursuit of a goal”. A common characteristic of all animals is a primitive drive to obtain basic physiological needs including water, food, social interaction, and reproductive sex (Simpson & Balsam, 2016) [22]. These are supported by primitive, neurologic pathways that are critical for survival (Di Domenico & Ryan, 2017; Kim, 2013) [7, 14].Theories of motivation have been proposed by scholars since the beginning of the 20th century. Sociologists and psychologists such as Hadley Cantril, Gordon Allport, and Abraham Maslow have produced s eminal theories into the origins of human motivation (Bertocci, P. 1940; Bertocci, P. 1942; Maslow, A. 1943) [1, 3, 18]. Prior to focused scientific inquiry into Motivational Neural Circuits (MNC), these theories provided the backbone of insight into what motivates humans. Early theorists of human motivation (Maslow, Cantril, Allport, and Herzberg) described common drivers of human motivation (causing humans to behave in goal-directed activity) based upon their observations of humans at work, at play and in society (Bertocci, 1940; Bertocci 1942) [1, 3]. This formed the basis of their general theories. In recent decades neuroscientists have attempted to find similar physiologic drivers of human motivation (at a cellular and molecular level) to attempt to describe what causes humans to behave in goal-directed activity (Di Domenico & Ryan, 2017) [7]. To this end, newer non-invasive neuroimaging technologies such as Single Photon Emission CT Scanning (SPECT), Functional Magnetic Resonance Imaging (f-MRI), and Positron Emission Tomography (PET) have been adopted and implemented to study the anatomic regions of the brain involved in motivation related neural activity, and to image the neurotransmitters and their receptors activated during cognitive motivational goal-directed activity (Di Domenico & Ryan, 2017; Eckstein, Braver, *et al.*, 2008; Heit, 2014) [7, 19, 10]. Are these theories just constructs of human motivation, or is there actual neurophysiologic evidence supporting the validity and reproducibility of these theories? This paper will explore some of the important theories of human motivation in the context of non-invasive neuro-imaging. Furthermore this paper will attempt to provide insight into the neurophysiologic underpinnings of human motivation through the use of brain imaging.

Maslow’s Theory of Motivation

In his paper, A Theory of Human Motivation (1943) Abraham Maslow proposed that humans are motivated based upon a hierarchy of needs. Maslow has claimed that the hierarchy of needs is a substrate for human motivation directly, and human behavior indirectly. He has described four levels of needs that must be satisfied sequentially in order for an individual to flourish. The first and most important level of need, which is a driver of motivation is the physiologic needs level. Maslow described physiologic needs to include the provision of food, water, clothing, sexual instinct, and shelter. Once these primary needs are satisfied other higher levels of motivation can be addressed. The next stage in Maslow's hierarchy of needs is safety and security. He described the need for personal security, financial security, health and well- being, and safety as drivers for this level of motivation. Once these needs are met higher levels in the hierarchy can be addressed. Following this the next stage is social belonging. Maslow described the intrinsic human need for social interaction and social belonging. He described these needs to include friendships, intimacy, family, and community involvement. He believed that these needs are essential to the perpetuation of culture. The next stage proposed by Maslow is esteem. The primary drivers of motivation at this level in the hierarchy include self- esteem and self- respect. Maslow believed that this was an important high level of motivation for humans to function in society. The last stage in the hierarchy of needs is self- actualization. Maslow describes self- actualization as the process of living life to one's fullest and greatest potential. Typically the stage of self-actualization is one that is manifested in later stages of life, and remains a potent driver of motivation and human behavior.

Neuroimaging Correlation

Newer brain imaging technologies such as functional- MRI (f-MRI), Single Photon Emission CT Scan (SPECT), and electroencephalography (EEG) now permit the observation of the neurologic pathways involved in extrinsic and intrinsic motivation (Di Domenico & Ryan, 2017) [7]. Functional MRI imaging performed on fasting subjects shown images of food and water demonstrate increased cortical activity in the regions of the prefrontal cortex, nucleus accumbens, and dopamine D2 receptors of the anterior insular region (Di Domenico & Ryan, 2017) [7]. This activation is consistent with Maslow's physiologic needs level in his description of the hierarchy of needs. Delayed post-prandial and post-hydration imaging of the same subjects demonstrates a reduction in dopamine D2 receptor activation in the anterior insular region indicative of satiety (fulfillment of Maslow's physiologic needs level on the hierarchy of needs). This type of brain activation is consistently seen when controlling for age, gender, and ethnic origin (Di Domenico & Ryan, 2017) [7].

Eckstein and associates (2008) [19] have conducted reward-relevant experiments utilizing functional MRI. This type of experiment demonstrates the signaling activity of food in the medial -frontal cortex, lateral- frontal cortex, and the parietal lobe of the brain. The effects are analogous to the first level of Maslow's hierarchy of needs. The expectation of reward in the form of food becomes a sentinel event in the motivational neural circuitry. From this it is evident that individuals will work hard to receive a reward in the form of fulfillment of a basic physiological need (Eckstein, Braver, *et al*., 2008) [19].

Similarly, Heit (2014) [10] has demonstrated the effects of deductive reasoning utilizing meaningful and non-meaningful events on brain neuro-imaging. Activation of the brain higher centers (nucleus accumbens) in evaluating meaningful experiences and events is analogous to Maslow's self-actualization level in the hierarchy of needs, and demonstrates neural correlates of self-actualization (Heit, 2014). Maslow's Theory of Human Motivation is further supported by work by Fox and associates (2015) [9]. Fox and Kaplan *et al* (2015) [9] conducted a brilliant experiment demonstrating brain activation during gratitude. Functional MRI imaging was obtained on test subjects viewing pictures of army vets returning from war zones, Red Cross workers conducting disaster relief operations, and EMS workers helping victims of a car-crash. All test subjects indicated high activity in the medial pre-frontal cortex and lateral parietal lobe, consistent with known areas of brain activity during gratitude. Gratitude is an important component of both Maslow's social belonging level and the self-actualization level. Being in community and having social interactions can be expressed by gratitude. Similarly, at the highest level of self-actualization, one has a perspective of gratitude. Neurophysiological evidence of Maslow' hierarchy of needs as a component of human motivation is once again elegantly demonstrable on f-MRI imaging (Fox, Kaplan, *et al*., 2015) [9].

Further neuroimaging support for Maslow's first level in his hierarchy of needs is demonstrated in studies conducted by Levine (2015) [16]. Levine has described how hypothalamic-physiologic needs such as eating, drinking, and sex are mediated through motivational circuitry and networks in the motivational regions of the hypothalamus and brain stem. Initiative and motivation to fulfil these needs can be demonstrated on EEG and functional MRI. Once again, this demonstrates the neurologic correlates of human motivation as described by Maslow in the first level of his hierarchy of needs model.

Neuroimaging studies conducted by Xue and associates (2010) [23] further demonstrate the role of social decision making in Maslow's Hierarchy of Needs model of human motivation. Social decision making is an important component of the social belonging stage of Maslow's hierarchy of needs. Balanced social decisions are critical to maintain ties with other individuals and to become a fully evolved member of society or a community. Xue, Chen and associates (2010) [23] have demonstrated neural pathways involved in social decision-making. Key brain areas involved in this type of decision-making process have been demonstrated on f-MRI and SPECT imaging. The ability to image the neural circuits involved in social decision making again provides credible evidence for the neurophysiological underpinnings and validity of Maslow's hierarchy of needs model of human motivation. Thus, there is demonstrable neuroimaging evidence for the validity of Maslow's theory of motivation.

Allport's Theory of Motivation

Gordon Allport proposed a theory of motivation based upon his construct of traits (1936). He proposed that humans were motivated based upon their underlying traits. Peter Bertocci

(1963) from Bates College critiqued this theory and challenged some of the important components theorized including the life-long persistence of traits. He felt that the trait is primary and that an individual's motivation and subsequent behavior was based upon their underlying trait. For example a child who grew up in an oppressive environment would be very afraid of trying new things in life and school, and would subsequently rely on fear as the primary motivator. He also felt that in contrast to Maslow's theory of motivation, motives were separate and distinct from drivers. Once a motive had been achieved, it became independent of the driver, and it was this driver that continued to perpetuate the behavior involved. This can be seen in the case of an individual learning to play the piano. Initially, the person is motivated to learn how to play the piano at a functional level. Once he is completely functional in playing piano, the motive is no longer important, yet the drive for perfection dominates.

Neuroimaging Correlation

SPECT and f-MRI imaging of participants playing a video game in a state of flow (indicating mastery) have been shown to have increased brain activity in the reward center of the brain in the nucleus accumbens and the amygdala (indicative of high levels of pleasure) (Di Domenico & Ryan, 2017) [7]. This demonstrates the separation of motivators and drivers in Allport's theory of motivation. Allport's theory of human motivation receives further neuroimaging support from Klasen and associates (2012) [15]. Klasen, Weber, and associates (2012) [15] conducted elegant experiments on 13 male subjects playing video games while in a state of flow. Functional MRI imaging obtained during flow demonstrated increased activation of the reward circuitry in the nucleus accumbens and the medial prefrontal cortex consistent with reward activation. Allport's theory of motivation describes achieving mastery of a complex task as being in a state of flow. Functional MRI imaging provides evidence for the validity of flow being a true neurophysiological state. This is true regardless of cultural bias. Mao, Roberts and associates (2016) [17] have shown that neurological correlates of flow (intrinsic-motivation) transcend culture and are virtually identical in Spanish, Chinese, and American workers. Once again, this shows that Allport's theory of human motivation is more than just a construct, and indeed has a neurophysiological basis that can not only be demonstrated through neuroimaging modalities such as PET, SPECT, and f-MRI, but also can be replicated across cultures, when controlling for age and gender.

An elegant study conducted by de Manzano and associates (2012) [6] demonstrated dopamine D2 receptor activity in striatum of the brain in 25 individuals with mastery of a video game. PET scans performed immediately after being in a state of high dopamine expression during flow (indicating mastery and pleasure) demonstrated increased dopamine D2 receptor activity in the striatum of the brain consistent with reward. This simple neuroimaging study supports Allport's theory in that proficiency leads to mastery, and mastery leads to flow, which is a state of reward demonstrable by increased dopamine receptor activity on PET scan. Studies conducted by Bromberg-Martin and associates (2010) [4] and Cheron (2016) [5] demonstrated similar findings in highly skilled musicians in a state of flow (appendix A & B). Therefore, mastery at any task is a reward in itself, as suggested by Allport.

Cantril's Theory of Motivation

Hadley Cantril was a psychologist primarily engaged in understanding behavior in a social context. His most important work would deal with looking at the psychology of social movements (Bertocci, 1942) [3]. Cantril studied the underlying motivation involved in social movements such as lynch mobs, and crowd behavior. His theory is different from Maslow and Allport in that he felt environment and social culture could be profound motivators of human behavior. His studies on individuals engaged in mob mentality activities including social protests revealed the powerful influences of other individuals as part of a culture of influence. This was a paradigm shift in theories of motivation and demonstrated that individuals do not function in a vacuum, and that motivation has a strong underlying social component particularly when individuals are from the same culture.

Neuroimaging Correlation

Functional MRI imaging of study participants engaged in a collective activity with a shared sense of purpose showed increased brain activity in the brain reward center of the nucleus accumbens and the amygdala on functional MRI scanning (Di Domenico & Ryan, 2017) [7]. This is direct evidence of the influence of shared culture and crowds on individual motivation and behavior and supports Cantril's theory on a cellular and molecular level.

The New Industrial Psychology and Theories of Human Motivation

Industrial psychologist Fredrick Herzberg studied motivation in industrial workers in industrialized nations in both communist- bloc countries and in the Western world (1941). He found that the primary motivators of the work were not related to financial needs or basic physiologic needs but were related to job satisfaction and autonomy in the workplace. This was similar in the communist- bloc countries and in the West, and was independent of ideologies. Workers performed better when given autonomy rather than when incentivized with a higher pay check.

Neuroimaging Correlation

Functional MRI imaging of study participants who had a choice in the color and design of a stopwatch when conducting timed trials (autonomy) had less errors compared to matched controls using a standard, predetermined stopwatch color and design (Di Domenico & Ryan, 2017) [7]. Functional MRI imaging of the study participants given autonomy showed increased brain activity in the regions of the medial prefrontal cortex, hippocampus, and left insula indicating "satisfaction" and "salience" (Di Domenico & Ryan, 2017) [7]. This again demonstrates that this early theory of industrial worker motivation has a neurophysiological brain mechanism that can be imaged.

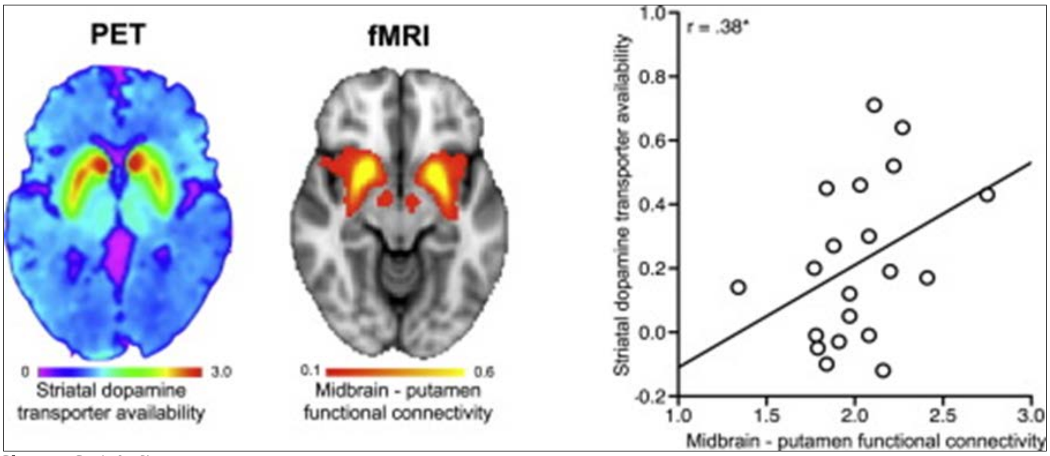
Factors that Attenuate or Potentiate Human Motivation

Theories of human motivation proposed by Allport, Cantril, Herzberg, and Maslow have suggested a stimulus- response, or cause and effect type of relationship between human needs and human motivation. Research by others (Fiske, *et al*., 2009; Shamay-Tsoory, 2011; Horton, 2012) [8, 21] has demonstrated that that the stimulus- response or cause and effect type of relationship between human needs and human motivation is not always linear and may in fact have attenuating or mitigating factors. Factors such as emotions can play a significant role in influencing whether an individual will be motivated or not. Roy and associates (2012) [20] have shown that emotions can play a significant role in influencing the motivational neural circuitry activation. Neurologic pathways in the motivational neural circuitry can be attenuated or potentiated by emotional bias, and this phenomenon is demonstrable on f-MRI and SPECT imaging of the brain. Their work is important in helping to build the case for the role of the ventromedial prefrontal cortex in providing emotional modulation to the motivational neural circuitry. Similarly, Zahn and Garrido and associates (2014) [24] have argued that humans are not motivated in a cookie-cutter type, cause and effect manner. Rather, there are important emotional- modulating factors like pride, gratitude, empathy, and compassion that can have a profound effect upon external motivation. In their study they describe the correlation between posterior cortical gray matter volume and emotional responses under functional MRI imaging. This supports the validity of the role of emotional bias in human motivation on a neurophysiological level. Empathy plays a significant role in human motivation and has been described before by others (Numennmaa *et al*., 2008; Fiske, *et al*., 2011). In his paper, A Theory of Human Motivation (1943) Maslow proposed that humans are motivated based upon a hierarchy of needs. Maslow's stages of social belonging, esteem, and self-actualization are all contingent upon interaction with other human beings. Studies by Fiske and associates (2011), and Numennmaa and associates (2008) have demonstrated that empathy may potentially attenuate social- belonging, self- esteem, and self-actualization. Fiske and associates (2011) discuss the ability of normal people to torture terrorists and prisoners of war in prison settings based upon their unconscious dehumanization of these individuals. Dehumanization has been defined by Fiske as a "complete absence of empathy leading to the inability to relate to the individual on a personal level". Functional MRI studies have demonstrated the areas of the brain involved in the genesis of empathy, and have also demonstrated the neuro-physiologic correlate involved in a lack of empathy (appendix C). Maslow's level of self- esteem and social- belonging in his hierarchy of needs is clearly attenuated by a lack of empathy. An individual will not seek self- esteem or social belonging from other individuals towards whom he has a lack of empathy. Once again, this can be demonstrated by the functional MRI studies performed by Fiske and associates (2009) [8] and Numennmaa and associates (2008). An elegant paper by Immordino-Yang and associates (2009) demonstrates once again that empathy and compassion have a quantifiable area of localization within the anterior insula, anterior cingulate gyrus, and the hypothalamus. Activation of these areas can be seen on functional MRI in response to provocative experiments. This further establishes Maslow's Theory of Human Motivation based upon the Hierarchy of Needs as a valid physiologic phenomenon, and more than just an abstract construct. Therefore, empathy serves as an important attenuating or mitigating factor in human motivation and human behavior. Fiske and associates (2009) [8] conducted an elegant experiment utilizing functional MRI to ascertain the effect of empathy, and underlying inherent-bias and stigma on human motivation. Others have demonstrated that primitive physiologic needs such as food, water, clothing, sexual needs, and shelter undergo a common neurophysiologic signaling pathway in the Motivational Neural Circuits (MNC) (Di Domenico and Ryan, 2017) [7]. Di Domenico and Ryan (2017) [7] demonstrated this signal arising in the medial prefrontal cortex, nucleus accumbens, and the insular region of the brain. Fiske and associates (2009) [8] conducted an experiment to determine if this neurologic signaling in the motivation centers of the brain in response to the need for food and water was always true. In the experiments the investigators asked healthy volunteers who had fasted for 24 hours what their favorite vegetable was and this was recorded. When shown images of these vegetables while undergoing functional MRI scanning the study subjects demonstrated neurophysiologic signaling in the motivational neural circuits. Conversely, however, when the same subjects were shown images of these vegetables in the hands of someone from a dissimilar race, or in the hands of a homeless person, or the hands of someone who was an obvious drug addict, functional MRI imaging in the same test subjects did not reveal signaling in the motivational neural circuitry. Thus, human motivation and subsequent behavior can be attenuated by conscious or unconscious bias based on cultural levels of empathy. Thus, at its most basic level this study demonstrates that a hungry man will be motivated to find food, however, the hungry man may or may not eat the food given to him by an individual against whom he has an inherent bias and lack of empathy. For example, a hungry man seeking food may not accept food offered by disheveled, dirty, homeless person, or a thirsty woman may not accept water from a leper.

In a similar study, Nummenmaa and associates (2008) demonstrated the locus of empathy to be in the limbic system on f-MRI studies of study subjects being shown images of elderly adults, stereotypical rich people, stereotypical homeless people, and stereotypical drug addicts. This study demonstrated a lack of cortical activation in the limbic system in the study subjects viewing images of homeless people, drug addicts, and rich people. Conversely, however, limbic system activation was seen in the study subjects viewing images of elderly adults, and families with smiling faces of the same race. Once again, this demonstrates the neuro- physiologic correlates of empathy, and the fact that empathy can play a role in attenuating human motivation, and subsequently human behavior.

Appendix A

PET scan and f-MRI imaging of dopamine transporter metabolism during flow-states in Video game playing study participants.

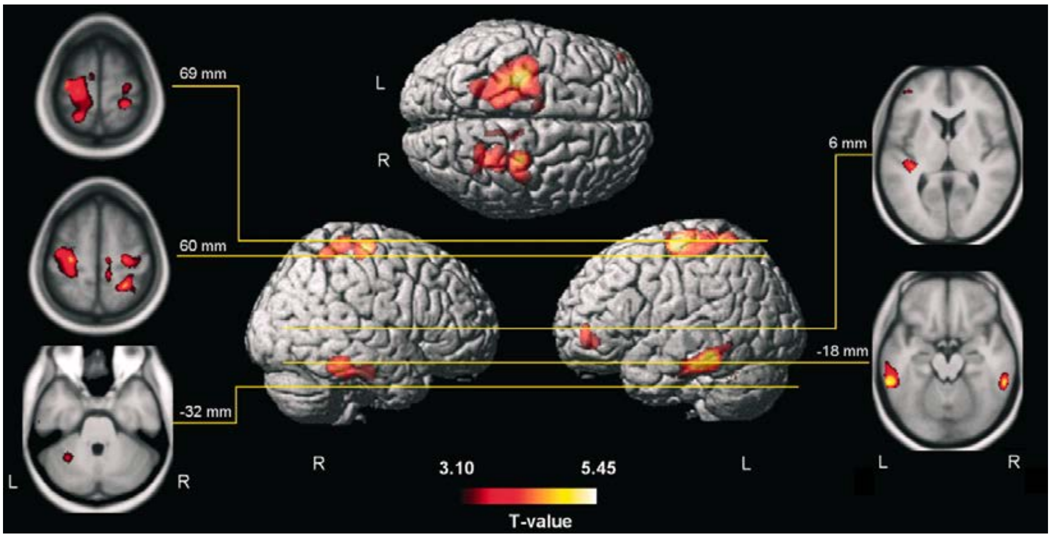


Cheron, G. (2016).

Fig 1

Appendix B

Brain activation during musical instrument playing indicating flow-state and dopamine transporters



Bromberg-Martin, E., Matsumoto, M., Hikosaka, O., (2010).

Fig 2

Appendix C

Brain activation during provocative experiments entailing empathy scenarios (Fiske, *et al*., 2011)

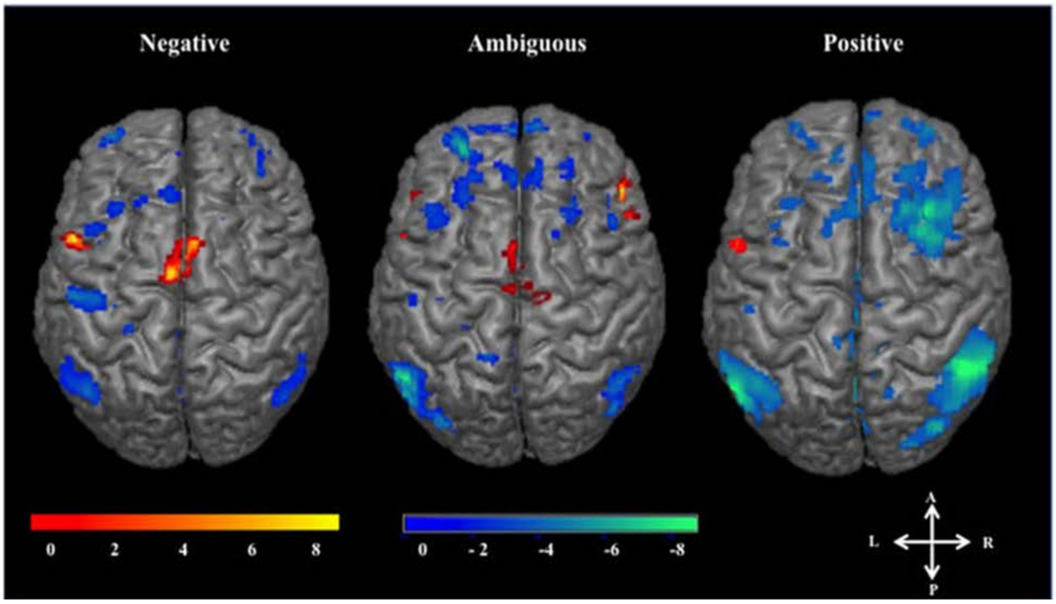


Fig 3

Conclusion

Numerous theories have been proposed by early scholars of human motivation including Maslow, Allport, Cantril, and Herzberg. The veracity of these theories can be demonstrated and understood at a cellular and neuroanatomical level through the use of newer brain imaging technologies including PET scanning, f-MRI and SPECT. Clearly, these early pioneers of understanding human motivation were ahead of their time, and exhibited an extraordinary comprehension of the now clinically demonstrable factors involved in human motivation.

In summary, theories of human motivation proposed by early pioneers in the field are, indeed, more than just constructs, and can be supported, validated, and reproduced through newer brain imaging technologies such as PET scanning, SPECT and f-MRI. While these theories of human motivation are valid, recent neuroimaging studies have demonstrated that they also may be attenuated by empathy and gratitude.

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