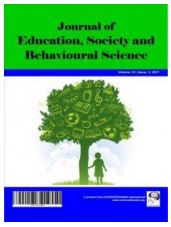

Journal of Education, Society and Behavioural Science

27(4): 1-9, 2018; Article no.JESBS.45333
ISSN: 2456-981X
(Past name: British Journal of Education, Society & Behavioural Science, Past ISSN: 2278-0998)

The Applications of Cognitive Mechanism of Verbal Humour to the Adjustment of Depressive Mood

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JESBS/2018/45333
Editor(s):
(1) Dr. Sara Marelli, Department of Clinical Neuroscience, Centro di Medicina del Sonno, San Raffaele Scientific Institute, Via Stamira D'Ancona, Italy.
Reviewers:
(1) Nnadi Mathias Nnanna, University of Calabar, Nigeria.
(2) Abdelaziz Tahbet, Mental health-Palestine, Al-Quds University, Israel.
Complete Peer review History: http://www.sciencedomain.org/review-history/27314

Method Article

Received 09 September 2018
Accepted 16 November 2018
Published 19 November 2018

ABSTRACT

Aims: To apply the findings of neurolinguistic research to the practical technological artifact design, the cognitive mechanism of verbal humour is comprehensively investigated and designed with EEG-based Brain Computer interfaces and Mobile Health, under the guidance of technology design theory, to help with the adjustment of depressive mood.
Application Base: The intervention effect of verbal humour on depressive mood is rooted in their cognitive mechanisms. The right hemisphere of the brain has a dominant effect on both verbal humour and depressive mood; some specific brain regions, such as amygdala, nucleus accumbens, hippocampus etc., are particularly activated during the processing of both verbal humour and depressive mood. The elicitation by verbal humour positively activate the brain regions related with depressive mood and even help to normalise them. In addition, the cognitive model of verbal humour processing greatly contributes to the transformation from the fixed and unchangeable mindset grounded in a depressive mood to the innovative and flexible way of thinking.
Application Methods: To integrate humour intervention into a set of solutions to objectively monitor and effectively mediate mood problems under the premise of privacy protection, Life-Based

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Design theory, a multi-dimensional design theory putting emphasis on the significance of comprehensively understanding people's life, provides the basis of the solutions. Portable Brain-imaging techniques are available to assist us in evaluating the real-time mood state. Mobile phone, as the most popular and indispensable Information Communication Technology device, allowing for bidirectional communication and on-demand access to resources with the precondition of privacy protection.

Conclusion: The merger of Life-Based Design theory and EEG-based Brain Computer Interfaces, combined with Mobile Health, presents a creative way to apply the verbal humour research to the technology design, bridging the gap between the cognitive linguistic studies and practical applications.

Keywords: Neural mechanism; cognitive model; verbal humour; depressive mood; life-based design; EEG-based BCI.

1. INTRODUCTION

Everyone has blue hours from time to time. Emotional problems are hidden but serious. Without intervention or treatment, those problems may get worse over time, giving rise to other physical and mental problems, and as a result, the emotional problems cannot be ignored. But how to overcome the struggling feelings brought about by negative emotions, like anxiety or depression? Since most emotional problems do not get cured on their own, it is advisable to seek help from families, friends and psychological consultants, or rely on medication to get the situations under control. However, in most instances, people would not like to confront their emotional problems due to the feelings of fear and embarrassment. What's more, it is known to us that long-term medication has risks of adverse side effects. Thus, there is still much work to be done in terms of developing approaches that will work for those with negative emotions to prevent the occurrence or the recurrence. Nowadays, the achievements of the rapid development of Information Technology are permeating every aspect in society and deeply impacting our way of life, so is it possible for us to utilise it to set up an intervention method, which can both objectively measure the emotional state of people and, at the same time, provide people in need with effective minor intervention?

It is common for people to cheer up by telling funny jokes to cope with negative feelings. Verbal humour, through the positive emotion of mirth, may potentially influence both psychological and physical health [1], and the evidence of it can be found in the neural mechanism of verbal humour processing. Taking depressive mood as an example, many brain regions related to it, such as amygdala, nucleus accumbens, hippocampus, etc., are also activated during the processing of verbal humour, which signifies that verbal humour processing will, in some way, stimulate the positive activations in those regions so as to alleviate the degree of depression. Besides, novel perspectives required to appreciate verbal humour motivate people to view things from different angles, helping them to overcome the difficulties in innovative ways. Thus, humour, as one of the effective intervention methods, has been prescribed as the "sweetest medicine" to cope with negative moods, stress, smooth social interactions, increase creativity and enhance life satisfaction and well-being [2].

However, how to integrate humour intervention into a set of solutions to objectively monitor and effectively mediate mood problems under the premise of privacy protection? First of all, a theoretical guidance is needed to structure the solutions by gluing every element for the implementation. Design technology is to design a better way to solve the actual problems. Life-Based Design theory, involving a multi-dimensional design theory putting emphasis on the significance of comprehensively understanding people's life [3], provides the theoretical basis of the solutions. Secondly, brain-imaging techniques are needed to assist us in evaluating the real-time mood state. The portable EEG (electroencephalogram) equipment, installed inside a normal baseball cap, is now available to make it possible. Furthermore, various sensors with low prices can also provide some other physical signs to assist in the evaluations on mood. Thirdly, mobile phone, as the most popular and indispensable Information Communication Technology device, allowing for bidirectional communication and on-demand access to resources [4], may act as the media to

help to carry out the new forms of intervention. To sum up, with the aim of adjusting emotional problems, the cognitive mechanism of verbal humour, used as the foundation of the solutions, is integrated with the emerging EEG-based Brain Computer Interfaces and Mobile Health to provide a real-time recording, instant feedback and effective intervention strategy in one system under the guidance of Life-Based Design theory, which is expected to explore an innovative design concept to bridge the gap between the cognitive linguistic studies and practical applications.

2. APPLICATION BASES IN COGNITIVE MECHANISM

2.1 The Overlap in Neural Mechanism between Verbal Humour and Depressive Mood

Neurons never function in isolation; they are organised into ensembles or neural circuits that process specific kinds of information and provide the foundation of sensation, perception and behaviour [5]. Similarly, the brain region is never activated alone. A number of intercorrelated brain regions, together with neuron activities, are integrated into neural mechanisms responsible for higher-level brain activities, such as cognition, emotion, attention etc. to regulate behaviour, voluntary and involuntary systems. Verbal humour appreciation can be segregated into three phases: incongruity detection, incongruity resolution and mirth. Thus, the neural mechanism of verbal humour consists of a series of continuous neuron activations in some specific brain regions across the above-mentioned three phases, which mainly involves the processing in cognitive aspect and emotional aspect. The studies on the neural mechanism of depression demonstrated changes in blood flow in several brain regions related with depressive mood: neocortex and hippocampus may mediate cognitive aspects of depression, such as memory impairments and feelings of worthlessness, helplessness, guilt and suicidality, and the ventral striatum or nucleus accumbens and amygdala are important in emotional aspects, resulting in anxiety and reduced motivation [6]. Generally speaking, there are some overlap in the neural mechanism between verbal humour and depression, manifest in right hemisphere and some specific brain regions, which lays the based for the application of verbal humour to emotional adjustment.

2.1.1 The dominant effect of the right hemisphere on both verbal humour and depressive mood

Verbal humour consists of written or auditory information and can be further differentiated into phonological versus semantic jokes, funny versus nonsense punchlines and funny versus ambiguous sentences [7], which decides the presentation of different forms verbal humour, such as jokes, limericks, puns, movie clips and so on. Despite different forms of stimuli activate correspondingly related brain regions, there is a convergence of the findings indicating a common processing mechanism of verbal humour.

In 1980s, Brownell conducted a series of experiments to lay a solid base for exploring the correlations between functions of right hemisphere and verbal humour processing. The first experiment [8] used verbal material to examine the sensitivity to humour in the right-hemisphere-damaged people and the results revealed that although they can recognise the form of the joke and try to choose the surprise endings, what they chose was not coherent with the setup of the jokes, implying that right-hemisphere-damaged people had difficulties in integrating the surprise and coherence elements in verbal humour processing; the second experiment [9] further investigated the sensitivity of right-hemisphere-damaged people to lexical denotation and connotation, critical factors in verbal humour and the findings showed that they had sensitivity to denotation, but selective insensitivity to connotative facets of meanings; a third experiment [10] indicated that people with right-hemisphere-damage had difficulties in answering inference questions and revising previously acquired knowledge in light of new information, an crucial ability in resolving the incongruities in verbal humour processing. Afterwards, researchers further generalised the correlations between right-hemisphere and verbal humour processing: from the perspective of cognitive aspect, Shammi [11] suggested that, due to the inabilities caused by right-hemisphere-damage to integrate the detailed information into coherence, the dealings with the incongruous information was hindered in humour processing; from the perspective of emotion aspect, Blake [12] indicated that the reduced ability in comprehending and expressing emotions among right-hemisphere-damaged people greatly affected their affective responses in humour processing.

A latest study showed that, to be able to overcome functional barriers, the right brain of depressive people must increase its activity level, resulting in the enhanced synchronisation performance in the right hemisphere, correlated with some abnormal brain areas in the right brain, such as right frontal gyrus, triangular part of the right frontal gyrus, and orbital part of the right inferior frontal gyrus [13]. In addition, a related EEG study in emotion recognition tasks found that higher right frontal activity was associated with negative emotions and higher left frontal activity was associated with positive emotions [14]. Individuals with higher right frontal lobe activity have stronger negative emotions than individuals with higher left frontal lobe activity [13].

To sum up, the right hemisphere has a dominant effect on both verbal humour processing and the processing of depressive mood. Thus, if suitable verbal humour stimuli are utilised regularly to stimulate brain regions related with depression in right hemisphere, the corresponding functional abilities in those brain regions will be improved to complete verbal humour tasks by overcoming the barriers in dealing with the incongruities, helping reverting those brain regions to the normalised states. Besides, the positive emotions elicited by mirth of verbal humour may also intervene the functional decline and deficiencies caused by depressive mood.

2.1.2 Some specific brain regions are correlated with both verbal humour and depression

Amygdala has specific functions in how we perceive and process emotion. There are functional differences between the right and left amygdala: electrical stimulations of the right amygdala induced negative emotion; while stimulation of the left amygdala was able to induce either pleasant or unpleasant emotions [15]. To probe the functions of amygdala in verbal humour processing, researchers conducted two experiments by fMRI: the first experiment [16] showed that the humourous stimuli activated bilateral amygdala and the nonhumourous stimuli activated left amygdala, which suggested that the amygdala has a critical function in the detection of optimal relevance in verbal humour; the second experiment [16] showed that the nonsensical sentences activated the right middle temporal gyrus and the medial frontal cortex, while humourous sentences activated the medial frontal cortex and the left amygdala related with positive emotion. To analyse the functions of amygdala from the angle of depression, functional imaging studies acquired during behavioral or neuropsychological challenge suggest that the physiological responsivity of the amygdala differentiates depressives from healthy controls, with the positive correlations between neurophysiological activity in the right amygdala and depression severity, reflecting the amygdala's role in organising multiple aspects of emotional responses [17]. Therefore, humour intervention is expected to normalise amygdala in individuals with depression so as to intervene in the formation and relapse of depression.

The nucleus accumbens plays an important role in the anticipation and experience of pleasure and reward [18]. The experiment conducted by Mobbs et al. [19] presented evidence that nucleus accumbens played a key role in the mesolimbic dopaminergic reward system and the degree of humour intensity was positively correlated with the BOLD signal intensity in these regions. However, decreased positive affect in response to reward in individuals with depression is consistent with functional MRI results, indicating that nucleus accumbens' activity decreased more dramatically in individuals with depression than in healthy controls during the period following positive stimulus presentation (Heller et al, 2009). The depression was associated with the reduced nucleus accumbens responses to rewards [20].

The hippocampus plays a vital role in learning and memory, contextual fear conditioning, and neuroendocrine regulation [21]. Verbal humour stimuli revealed enhanced activation in the right hippocampus [22]. The subcortical regions in bilateral amygdala and bilateral hippocampal gyri are responsible for the feelings of amusement during elaboration process in verbal humour processing [23]. However, the shrink of hippocampus precedes depression, and even predisposes towards depression [21]. To stimulate the activations of hippocampus by verbal humour material will help prevent it from shrinking to curb the depressive mood.

2.2 Adjustment of the Cognitive Model

The cognitive model describes how people's perceptions about a certain situation influence their emotional and behavioral reactions, which tends to be focused on a single cognitive process and how the processes interact to make

behavioral predictions for a specific task. The cognitive model of verbal humour is rooted in its cognition stages, manifested in the classis humour-related theory, Incongruity Theory, put forward by Suls [24]. The verbal humour processing resembles a problem-solving process (see Fig. 1): After the setup of a story or a joke, we make some predictions towards the ending, and if the ending is not like what we have expected (the 1st stage of verbal humour processing: incongruity detection), we have to figure out some ways to make sense (the 2nd stage of verbal humour processing: incongruity resolution); once we find out the particular ways to make sense between the set up and the unexpected ending, laughter occurs (the 3rd stage of verbal humour processing: mirth). This predominating theory presented the essence of verbal humour, which is to view people, situations, and events from the innovative perspective to resolve the incongruities or seemingly incompatible relations among things.

The cognitive model of depression is grounded in some built-in factors, such as social factor, psychological factor and biological factor. Some unpleasant individual experiences, overstress from the work, study or relationships with other people, neglect or poverty probably make people vulnerable to depression. People with depression often feel worthless, sad, guilty, or showing lack of interests in social activities. Some studies provided the indications that depression may sensitise people to everyday experiences of both social rejection and social acceptance [25]. According to Beck's [26] analysis, people with depression have their fixed and unchangeable mindset. For example, they usually have "if-then" statements ("If I don't do as well as others, then I'm a failure" or "If I trust others, and then I will get hurt") and also have difficulties in expressing the nature of reality without considerable outside help because of their deep cognitive structure. A person with depression displays a cognitive bias towards negative information and away from positive information, thus contributing to the maintenance of a depressed mood state [27]. Individuals with depression generally experience a positive blockade, in the sense that they have decreased capacity to process positive emotion. Besides, bad sleep, overeating and decreased appetite, low energy, fatigue, decreased interest in pleasurable stimuli etc. also affect the biological functions of people with depression.

Beck [28] mentioned that when we deal with people with depression, we must never lose sight of the gravity of their loss: the constriction of his capacity to feel pleasure, affection, gaiety, and amusement. The peculiar sounds of laughter have a direct effect on the listener, including positive emotional arousal that mirrors the emotional state of the laughter, by activating certain specialised brain circuits [29]. Via the way of transferring the angles of seeing difficulties to distance from fixed mindset, people, who maintain a humourous outlook on life, had fewer possibilities to suffer from the cognitive distortions leading to worrying or depressing feelings [30]. When people talk jokes, it seems that they can control and manage the situation and at the same time, they can release their bad mood. A recent studyexplored the verbal humour intervention on older adults by involving them in some improvisation training and the findings indicated the great benefits in increased positivity, increased sense of comfort, increased problem-solving abilities and a feeling of blending into the social activities [31]. Verbal humour uses the power of smiles and laughter to help recover from negative mood by changing the old way of thinking, viewing things from new perspectives, activating emotional-related brain regions, changing brain chemistry, and boosting the positive mood.

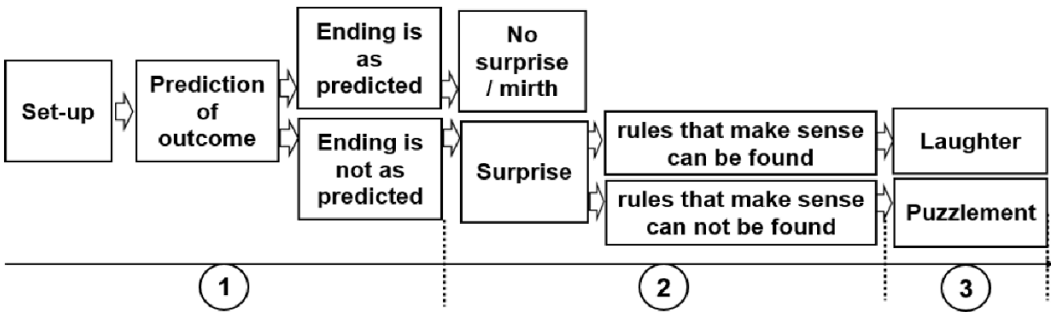

Fig. 1. Three stages of verbal humour processing in Incongruity Theory. Adapted from Suls [24]

3. THEORETICAL BASES: LIFE-BASED DESIGN

To apply the studies on the neural mechanism of verbal humour to the actual life to help people with depressive mood, a theory is needed to act as both a guidance and an adhesive, to turn a design idea into an innovative technical artifact. Life-Based Design, a multi-dimensional design theory, puts emphasis on the significance of comprehensively understanding people's life, including forms of life, values and circumstances, to ensure the technical artifact more human-oriented underlying design ideas and design concepts [32]. Investigating the structure of actions relevant to particular forms of life is the core tool of Life-Based Design, advocating the holistic analysis on humans from the perspectives of biological factor, psychological factor and socio-cultural factor [33].

The elementary step in Life-Based Design is to define the problem to be solved by connecting with practical Form-of-Life of target people on their biological aspect, socio-cultural aspect and psychological aspect; then, a design concept is proposed and a detailed description of how the new design concept can improve the human actions is intended to be illustrated; the third step is the actual design process, in which the design plan is divided into sub-problems and these problems are solved on the ground of the literature basis against the current technical contexts or advanced technical methods; the type of knowledge we need depends crucially on what the type of the target user group uses in daily life [34].

4. APPLICATION METHOD: TO INTEGRATE BY EEG-BASED BRAIN COMPUTER INTERFACES AND MOBILE HEALTH

In the context of continuous development of information technology, 'technology design' mainly refers to the design of the interaction between humans and computer systems, especially emerging information and communication technologies and systems [35]. The brain imaging method, like EEG, is a very effective tool to objectively record real-time Form-of-Life states in terms of brain responses. BCI is a state-of-the-art system, which measures the activities of the nervous system in the brain and converts them into visible and identifiable signals to record the interactions between the external stimuli and the internal responses in the brain. The merger of EEG-based BCI and Life-Based Design theory, integrating with the research on the cognitive mechanism of verbal humour processing, is an optimised innovative way to evaluate mood states and help intervene in the depressive mood [34]. The relationships of EEG-based BCI and Life-Based design are both fundamental and complementary for each other theoretically and methodologically. A major advantage of this merger methodology is its ability to examine human behaviors underlying neurophysiological level, and reduce self-reporting bias in behavior research [34].

Mere research on Form-of-Life analysis merging with EEG-based BCI cannot guarantee effective methods to realise the application. Information Communication Technology (ICT) is a most widely-used innovation having great effects on our way of life. Among various devices of ICT, mobile phone is the one most frequently used nowadays, and mobile phones can also serve as instruments to be utilised in health care. mHealth (Mobile Health care), a rapidly growing area that relies heavily on mobile applications and handheld devices, represents a new frontier for delivering mental health treatment [36]. Facing the emotional problems among people, the demand for individual face-to-face psychological guidance is already exceeding the mental health service supply in most countries, signifying new forms of intervention are needed to help people who suffer from mental problems [36]. The Life-Based Design with humour interventions based on the cognitive mechanism of humour will be feasible and effective technical artifact design plan for people with negative mood by providing them with an easy-to-reach, professional and objective way to deal with the problem.

The flow of the solution to the depressive mood based on the cognitive mechanism of verbal humour processing (see Fig. 2) begins with the identifying of the problem and the target population by analysing the Form-of-Life emphasised in the Life-Based Design theory; the rules of life in the target population showed their differences from other people in biological, psychological and social factors. Aiming at the people with depressive mood, by EEG-based BCI and Mobile Health, the objective brain data correlated with depressive state can be collected and analysed. The appropriate intervention by verbal humour stimuli will be then used to stimulate the brain regions correlated with depressive mood according to the research on

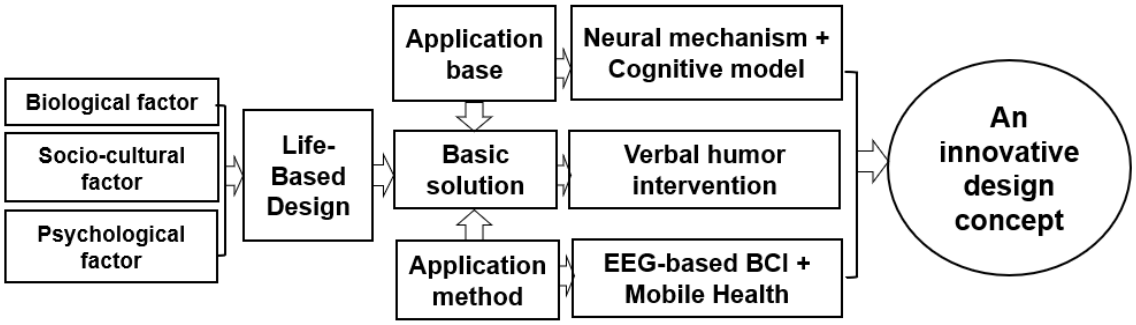

Fig. 2. The flow of an innovative design concept – to apply the cognitive mechanism of verbal humour to emotional adjustment

their neural mechanism and cognitive models. Then a set of solutions will be implemented in an innovative design concept under the guidance of Life-Based Design to apply the cognitive mechanism of verbal humour to the adjustment of depressive mood.

5. CONCLUSION

As we know, the health care services are confronted with the increasing demand from the psychological consultations, resulting in the increasingly dominant role of technology and software in assisting in the relevant services. New tools and methods are needed to monitor emotion in daily life and provide appropriate stimuli and responses in repeatable ways. A life-based design concept carries the characteristics of being more objective, more accurate, more effective and more practical by EEG-based BCI and Mobile Health to provide more comprehensive solutions to depressive mood resorting to verbal humour intervention. The overlap between the cognitive mechanism of verbal humour and depressive mood acts as the application base for the proposal of this design concept. Life-Based Design is human-centered design thinking, advocating the holistic analysis of Form-of-Life prior to the design research. It is a very important theory to bridge the gap between the laboratory studies and practical applications, helping shift product/technology – centered design to become more humanity. EEG-based Brain Computer Interfaces are the elementary method of recording brain signals, combining with different sensors to present the biological signal data for evaluating the mood state. Mobile health provides users with a number of functions in the design concept, such as information input, intervention tool and supervising system. A major challenge but also the strength in the practicality of this emotion design concept built on Life-Based Design is its multidisciplinary nature. We try to apply the findings of basic research to the practice and finally achieve the conversion between cognitive linguistic study and daily technical artifact. However, the conversion will of course need more specific in-depth research, test, re-research, retest and application.

ACKNOWLEDGEMENTS

This work was supported by the National Social Science Foundation of China under Grant 14ZDB155.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
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