JYVÄSKYLÄ STUDIES IN COMPUTING
283

Li Xueyan

Haha Moments

Applying Brain Research to Technology Design

JYVÄSKYLÄN YLIOPISTO

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Editors
Marja-Leena Rantalainen
Faculty of Information Technology, University of Jyväskylä
Timo Hautala
Publishing Unit, University Library of Jyväskylä

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ABSTRACT

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Mood problems are very damaging and far-reaching, affecting millions of people worldwide. More attempts should have been made by design researchers to form innovative and feasible design concepts, against current technological background, to produce practical technical artifacts to solve the issue. This monograph focuses on Design Science research and its collaboration with Neuroscience to seek ways to help people with negative moods, depression in particular. Humor, exerting positive influences on both physical and mental health and impacting every aspect concerning social interactions, is worth investigating. Studies on the cognitive processing mechanism of humor appreciation provide knowledge bases, evaluation methods and intervention tools to bridge the gap between Neuroscience research and Design Science research to facilitate the creative design processes, leading to the transfer of positive influences of humor to the technical artifacts by assisting people in regulating their emotions.

Rather than emphasizing the technological factor in this emotion design concept, this study was more immersed in the problem itself to recognize the natural states of the potential users via the analysis of Form-of-Life, which prevented us from being constrained by software solutions in isolation. On the basis of Life-Based Design theory, the desired emotion design concept, presented in 5Rs model, was proposed in this monograph. Resorting to mobile phones as the main media connecting potential users and future technical artifacts, this model was integrated with the emerging EEG-based Brain Computer Interfaces to provide a "three in one" system: real-time recording, instant feedback and effective intervention to lay more objective and reliable foundation for the implementation of the future technical artifacts.

Keywords: Humor, Neuroscience, Life-Based Design

Author Xueyan Li
Faculty of Information Technology
University of Jyväskylä
Finland

Supervisors Pertti Saariluoma
Faculty of Information Technology
University of Jyväskylä
Finland

Tapani Ristaniemi
Faculty of Information Technology
University of Jyväskylä
Finland

Huili Wang
School of Foreign Languages;
Dalian University of Technology
China

Fengyu Cong
Department of Biomedical Engineering
Dalian University of Technology
China

Reviewers Teresa Bajo
University of Granada
Spain

R. Ignacio Madrid López
ILUNION Technology & Accessibility
Spain

Opponent Jose Cañas
Faculty of Psychology
University of Granada
Spain

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I am very lucky to have Professor Tapani Ristaniemi as one of my supervisors, who guided to complete my research plan. I really appreciate him for his supporting letter so that my husband and my daughter were permitted to come to Finland to get a family reunion with me, which gave me the courage to go on with my study overseas.

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The author's affiliations also include: School of Foreign Languages, Changchun University of Technology, China; and School of Foreign Languages, Dalian University of Technology, China.

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Xueyan Li

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1 INTRODUCTION

1.1 Research motivation and background information

Have you ever experienced the following situations? Some friends were sitting around to talk about something funny and the responses of them differed: some of them laughed hard, while some of them looked clueless. When we were young, we did not understand why adults laughed at some jokes that we did not feel funny at all, whereas when we are adults, sometimes we are puzzled about why the kids have great laugh at something that we think of uninteresting. Everyone enjoys humorous scenes causing laughter, which seems very common, and humor appears to be understood easily, but why do people from the same background have different responses to same jokes? Why do people prefer humorous expressions rather than plain expressions? Why are men good at telling jokes very attractive to women? Why do people in different ages enjoy different types of jokes? How does the brain work when we appreciate humor? Can we move the laboratory research of humor to the real life, making the research meaningful for people? Can we use humor to help people with negative mood? Can we utilize the popular advanced technology, such as Artificial Intelligence and Brain Computer Interfaces (BCI), to design, through Design Science Research knowledge, a humor-related technical artifact to benefit people? I am one of the persons who are curious about the above-mentioned questions, so I started my studies in humor research and Design Science research, against the current technological context, to make endeavors to find out its way out in the application.

Humor is all around us, with ludicrous shows on TV, laughable expressions in advertisement, jokes in magazines and internet, amusing people in public places. We can also hunt for humor sources on our own by watching comedy movies and enjoying jokes with friends, so laughter can be heard almost in all occasions. Though each culture has its own customs and habits on the suitable topics of humor, “the sounds of laughter are indistinguishable from one culture to another” (Martin, 2010). The ubiquity of humor decides the research on it is multidisciplinary, involving a great number of research fields related to language, culture, literature, cognitive process etc., which, on the other hand, also points out the complicacy of humor appreciation as a high-level cognitive task. However, an overview of the humor-related research reveals that cognitive humor study lacks systematicness and unity for being disjoint from practical applications, resulting in the scattered and fragmentary research situations.

The development of cognitive science encourages the exploration on the brain on various topics, such as how the brain functions when we see, hear, read, understand and create things, how the brain controls the interplay between the cognition and the emotion, and how to achieve higher-precision brain imaging methods to further the relevant research. The study in the cognitive process in humor appreciation has also been listed as one of the research interests to explore the brain, attracting the attention of a great number of scholars and providing substantial objective evidence on clarifying the correlations between the cognition and the brain. Besides its important values in cognitive study, humor research also has its great practical values in daily lives. As the most effective communicative tool that people use to interact with each other in diverse ways, humor enjoys its significant role in social perceptions and interpersonal relationships. Its close correlations with physical health and mental health bring about enormous influences on people's well-being. Other than that, the research on linguistics of humor laid foundation for the set-up of computational humor models, a step forward towards the realization of Artificial Intelligence, having strong impacts on human-being's way of living in the near future.

How to transfer the research findings of cognitive processes in humor appreciation into an effective tool or a technical artifact to realize its positive values to the full to help people in need, is a topic worth investigating. Cognitive study should not limit itself to the study of mental processes in isolation. To move laboratory experiments into the natural contexts or try to free the cognitive science to the application, a design concept is needed to bridge between cognitive research and technical artifacts. With the guidance of Design Science research, on the basis of Life-Based Design theory, the desired design concept, presented in 5Rs Model, was proposed in this monograph, laying the first stone for the implementation of future relevant technical artifacts.

1.2 Design Science research and its collaboration with Neuroscience

Numerous technical artifacts, covering all man-made things and modified natural phenomena, have fundamentally changed people's way of life. Thus, how to better design technical artifacts to help human facilitate their daily lives, improve their quality of life and boost their happiness naturally becomes the core issue discussed in Design Science research, whose multidisciplinary variations decide a general guidance needed to overcome the general significant problems across different disciplines. For example, with the development of Information Technology, Information Systems have evolved into an indispensable role in people's life, penetrating into every aspect of society, and the challenges they are facing in this field require novel solutions, as requirements are often unstable and often call upon cognitive skills in developing solutions (Hevner, 2010).

The rapid development of cognitive science provides easy access to brain data and presents more objective evidence on cognitive and emotional processes, resulting in the joint research of neuroscience and Design Science research in Information Systems. The specific functions of Neuroscience research can help meet the demand of elements proposed in Design Science and the collaboration of them is to produce more fruitful results by providing more objective, more valid and more reliable evidence by brain-imaging techniques, which is quite effective to help to detect problem relevance, establish the rules for research rigor and explore the solutions to the problem. "We have reached a tipping point where the fields of neuroscience and Design Science in Information System are able to collaborate to identify and frame fundamental questions about the relationships between creativity, design, innovation and research (Hevner, 2014)."

1.3 Human-Driven Design and Life-Based Design theory

One of the serious issues we are confronted with in modern society is the negative influences of negative moods on people's lives. In 2012, WHO (World Health Organization) reported that depression ranked the most damaging and far-ranging problem and affected 350 million people worldwide. Again, in 2017, WHO indicated the gravity of depression, which pointed out that, due to fear of prejudice and discrimination, even when services are available, many people suffering from depression avoid or delay treatment, leading to the failing to receive appropriate help. Under this circumstance, what researchers in relevant field should focus on is to utilize effective intervention methods to assist people in conquering depression via popular media which can eliminate people's fear and create private and safe environment to cope with it. How to make use of the positive influences of humor on negative moods, combining the findings of research on cognitive process of humor with today's advanced technology in Information Technology, is the fundamental starting point of the design concept put forward in this monograph.

The formation and the implementation of a holistic human-driven design concept applicable to most areas is the key to turning technology into future artifacts to practically serve people. The Human-Driven Design (Braund and Schwittay, 2006), a leading Design Science theory, centering on the holistic perspective of Human Technology Interaction (HTI), emphasizes that the purpose of the design should be designing solutions for human or societal problems and not just solutions for and within a certain technology (Niemelä et al., 2014), which has great significance in Design Science research for its calling for the transferring of technology-driven force to the human-driven force in technical artifact design. Life-Based Design theory, a more specific theoretical framework, identifying with Human-Driven Design and advocating the holistic analysis on humans from the perspectives of biological factor, psychological factor and socio-cultural factor (Saariluoma et al., 2016) prior to the design concept, has advantages over other relevant theories in both theoretical sense and practical sense.

To collect solid and reliable data in different factors, we need to depend on the current advanced technology. In the context of continuous development of information technology, 'technology design' mainly signifies the design of the interaction between humans and computer systems, especially emerging information and communication technologies and systems (Niemelä et al., 2014). The design concept presented in this monograph is to highlight the data collection of different factors, biological factor in particular, to provide more objective and valid evidence on the evaluations on people in real-life contexts by extracting real-time brain signals via portable brain imaging methods with the support of information technology systems.

1.4 The significance of humor on health

The ultimate goal of any research should focus on the improvement of people's well-being. To design a technical artifact to better people's emotion state to enhance their well-being, an effective intervention method is essential. Due to humor's ubiquitous feature, it exerts great influences on many aspects concerning human-being, including both physical health and mental health: the laughter caused by humor is a kind of exercise, promoting the blood circulation; the pleasant mood accompanying humor appreciation helps to improve the immune system and release the pain; and more importantly, the transformation from a fixed angle to an innovative angle to resolve the incongruity in humor enables people more solutions to the difficulties in lives, helping to conquer stresses and various negative moods. In a way, humor can be used as both a kind of medicine to fight against diseases and a coping strategy to handle emotional problems. Especially for the aged people, humor plays a vitally important role in dealing with the problems brought by aging. In addition, as widely accepted as the most effective communication tool, humor has great effects on people's social lives, resulting in the increase of life satisfaction. Through the harmonious atmosphere built up by humorous way of interactions, humor can also be used as an intervention strategy to alleviate stress and tension, fostering more optimistic outlook on life.

1.5 To integrate to serve haha moments

In view of the heavy load the health care system is facing in most countries, more attempts should have been made by design researchers to set up innovative and feasible design concepts against current technological contexts to solve this social issue. Considering humor's large amounts of positive influences on both physical and mental health, why not design an acceptable and effective humor-related technical artifact, based on humor's cognitive processes, to produce haha or happy moments for people in bad mood by utilizing the omnipotent and popular information system? Thus, in this monograph, humor was comprehensively studied from as many angles as possible with the purpose of providing more extensive evidence on applying it to the technical artifact design to serve haha moments. Studies from various angles not only helped us deeply understand humor's profound meanings for human being, but also inspired us to produce more innovative ideas on how to efficiently and objectively integrate it into the design concept to bring its values to the full by taking the advantage of advanced technologies.

The base of humor was a very important aspect we had to discuss in this monograph, for it not only formed the basics of the current research, but also concerned every possible effect the future relevant technical artifact will bring to us during its practical application. As Design Science researchers, we were required to have holistic understandings on the effects caused by the potential technical artifact so we had to comprehensively research humor, such as its concept, its sources, its theories, its impacts on society, cognition and affection, its different influences on different people in different languages with different personalities, different genders and different ages, and so on.

Cognitive process in humor appreciation was the key aspect in this monograph because it laid the foundation for the proposed design concept, and more importantly, the brain-imaging method used in investigating the cognitive processes gave us a brand-new and innovative angle to conduct the Design Science research. For example, combining with brain imaging method, it's possible for us to know more about how to explore humor processing mechanism, how to get real-time responses on the specific stimulus, and how to evaluate the effects of humor intervention strategies. The pilot study I conducted was actually a first step of a series of experiments on humor processing mechanisms across a lifespan, aiming at gaining solid evidence on the differences of humor appreciation for different ages and then providing more data findings to design distinctive humor interventions according to the needs of people with different conditions.

Computational humor is a step forward to Artificial Intelligence. As design researchers, we cannot ignore this widely infiltrating and influential technology with such a sense of times. In this design concept, computational humor was one of the important intervention strategies to help enhance positive mood through automatically identifying humor and generating humor by machine learning.

The relationships between humor and health acted like a guiding star, directing the goal and the formation of the concrete implementations in this emotion design concept. Life-Based Design is human-centered design thinking, advocating the holistic analysis of Form-of-Life from the perspectives of biological factor, socio-cultural factor and psychological factor before the design research. It is a very significant theory, which helps to shift product/technology–centered design to become more humanity. EEG-based Brain Computer Interfaces are the elementary method of recording brain signals, linking 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. With all above-mentioned research as the bases, the design concept for haha moments was possible to come into being, more attempts being needed to improve it though, hoping it can be helpful for people in need.

1.6 The structure of the monograph

In the second part, Design Science and its collaboration with Neuroscience was the highlight, which plays the roles of both knowledge base and research guide in this monograph, showing the future trend in Design Science research field. In the third part, Life-Based Design, derived from Human-Centered Design, acts as the theoretical base during the formation of the design concept, which emphasizes the holistic research on the artifact users prior to the investigation into the concept design.

The conceptual study of humor in the fourth part was the infrastructure underlying the current research. Although there is not an umbrella definition containing every element involved, the analysis of three components rooted in humor: social component, cognitive component and affective component, in some ways, presented the relatively comprehensive connotations of humor. In terms of social component, humor is originally a social phenomenon, indicating social relationships and complicated links among people. In terms of cognitive component, the core of humor is the conflict between two incongruous or inconsistent ideas or things. In addition to intellectual response to humor, emotional response is the main reason why people enjoy humor, revealing the affective component of it. Furthermore, the in-depth connotations of humor also reflect its significant benefits on people both as individuals and in groups in social communications, cognition processes and affective regulations. The theories supporting humor research were grouped into two categories by putting stress either on cognitive process or on social functions. The Incongruity Theory, as a dominant theory, formed the theoretical foundation in the research on humor processing mechanism. Four humor styles, the factors influencing humor appreciation (such as personality, gender and aging) and sense of humor were also incorporated into the bases of humor, paving the way for the proposal on the design concept.

The fifth part, Cognitive Processes in Humor, the kernel part in this monograph, constituted the solid ground for the proposition of the design concept. Starting with the relationships between humor and cognition, the cognitive process of humor in the brain damage was reviewed to locate the relevant brain regions mainly responsible for humor appreciation: right hemisphere and frontal lobe. Furthermore, according to different research goals, the relevant research literature was teased out and classified in terms of four dimensions: space dimension, time dimension, frequency dimension and multimodality dimension. From the perspective of space dimension, scholars mainly employed fMRI (functional magnetic resonance imaging) as the research tool to explore the neural correlates of different aspects of humor, including different stages of humor appreciation, particular brain functions related to humor, brain regions activated by different types of stimuli, brain connectivity in humor processing, brain regions relevant to personalities in humor appreciation, brain regions related to reviewing effects, brain regions in humor creation and the effects of current stimulation in humor processing. From the perspective of time dimension, EEG (Electroencephalograph) was used as the primary research method to explore the relations between different ERPs (Event-related Potentials) components and different types of jokes or different factors influencing humor processing, with different processing mechanisms of verbal humor and non-verbal humor being illustrated.

Since most of the humor-related cognitive processing studies are based upon alphabetic languages, elementarily different from Chinese characters, I conducted a pilot study by ERPs to specifically investigate the cognitive process of Chinese verbal jokes for providing the evidence on the emotional design concept on Chinese language. This pilot experiment, currently aiming at adults, is the first step of the study on the cognitive process in humor appreciation over a life span and the subsequent experiments will focus on children and aged people. The findings of this pilot experiment suggested that P200 effect was specific to the appreciation of Chinese verbal jokes, which was also a preprocessing stage prior to humor detection. What’s more, by using the method of Principle Component Analysis, the results manifested that, in the stage of humor detection, there were two components existing in the time window of 400 milliseconds: one was the classic N400 and the other was P400. Both classic N400 and P400 contributed to the N400 semantic effects and incongruity detection in humor processing.

The sixth Part presented clues to trace the similarities of cognitive linguistics and humor language, with the drive of evolving universal theory of language within Chomskyan linguistics. The linguistics of verbal humor is closely related to different theories of cognitive linguistics, such as construction grammar, embodied grammar and metaphor, which provided the base for the development of computational humor models to either identify or produce humorous language by machine learning. The computational humor plays an important part in the design concept as one of the main humor recognition and intervention method.

The seventh part focused on the connections between humor and health, structuring the driving force to transfer the relevant research into the emotion design concept. Humor helps to improve cardiovascular system, immune system and pain tolerance through muscle relaxation, positive emotion, different cognitive mechanisms, and optimistic outlook on interpersonal relationships. As a coping mechanism and an intervention technique, humor has been proved effective to enhance positive mood in different situations. Based on the close relationships between humor and health, a design concept of applying the research results of humor processing mechanisms to the technical artifact was then put forward in the eighth part, guided by Life-Based Design theory. The design concept was conceived to shift more attention and resources to preventive care and micro intervention to help people detect the emotional problems earlier and overcome the negative moods. A 5Rs Model, highlighting real-time biosignals recording, was presented to assist in detecting abnormal signs of negative emotions in the process of appreciating humor stimuli and provide potential users with instant feedback and humor intervention if needed.

2 DESIGN SCIENCE RESEARCH AND NEUROSCIENCE

2.1 Technical artifact, Engineering Design and Design Science

Technology development has changed people's way of life with numerous inventions of technical artifacts, which liberate humankind from hard labor, leading to the improvement of life satisfaction. And, at the same time, technology development provides more possibilities to design more sophisticated and advanced technical artifacts, which in reverse propels technological progress. Technical artifacts cover all man-made things and even a modified natural phenomenon that is employed to help human fulfill their goals, enhance their performance and improve their quality of life (Simon, 1969). The process from artifact designing, artifact production to artifact consumption, pervading every aspect in the world, constitutes the core task of human being.

With the uninterrupted development of science and technology, the process of artifact realization becomes increasingly complicated and Engineering Design then emerged as the times required, referring to the process of applying a variety of techniques and scientific principles to the building of a device, a process, or a system to realize its usability (Taylor, 1959) to present solutions to problems not solved before, or new solutions to problems in a different way (Hurst, 1999). It can be briefly understood as technology, mainly involving people and technical artifacts. Besides concentrating on the artifact designing, Engineering Design also takes human activities into consideration, being broad enough to incorporate different concerns. Modern Engineering Design highlights its complicated multidisciplinary feature and the distinctions among traditional disciplines, mechanical, electrical, and even chemical engineers are becoming blurred (Hurst, 1999). For example, Information Technology becomes an indispensable element functioning in most sections involved in the process of Engineering Design.

Engineering Design process is, generally speaking, a process of solving problems with rigorous standards by using systematic approach, involving a series of detailed steps, such as "define the problem, do background research, specify requirements, create alternative solutions, choose the best solution, do development work, build a prototype, test and redesign (Tayal, 2013)." This process can also be broadly grouped into four phases: "clarification of the task, conceptual design, embodiment design and detail design (Pahl and Beitz, 2013)." In these phases, some other key elements, such as concept evaluation, innovative concept design, prototyping, feedback and the like, are extensions of the listed items. Thus, due to the ubiquitous characteristic of technical artifact and the complicacy and variety of Engineering Design process, researchers put forward some theories or summarize some models to bridge the gaps caused by disciplinary variations and set general guidance in effective design method to guide the inclusive Engineering Design, and thus, Design Science arose in response.

As one of the early scholars researching Design Science, Herbert Simon (1969) distinguished Design Science from natural science: natural science involves the things or phenomenon in the world, describing and explaining the relationships among every element, and trying to understand what is the reality; Design Science, not in favor of just describing and explaining, involves the design of various artifacts to satisfy the needs of human being, to change the world and improve it. In brief, the natural science addresses "what is true", and by comparison, the design science deals with "what is effective" and "how to be effective" to create things that serve human purposes, and, to be specific, to "interface between the outer environment and the inner environment of the artifacts to meet desired objectives and knowledge about the uses of the artifacts and their interactions with people (Simon, 1969)." Design Science can be no independent discipline, and the supports from a few other areas of science make it possible to exert its influences, such as methodology derived from natural sciences, general working methods stemmed from philosophy and psychology, holistic thought rooted from informatics and effective usefulness proceeded from Ergonomics and sociology (Beitz, 1994).

Design Science then is mainly composed of "constructs, techniques and methods, models, and well-developed theory" for innovating technical artifacts, analyzing the performance and reflecting on the experience for improvement to map the functional requirements (Vaishnavi et al., 2004/17). What's more, Design Science does not limit itself to artifacts, but a set of system solutions to the existing and predicted problems having common features. It, aiming at practical problems human being is facing, usually results in solutions to the detected problems, solutions to the new problems, routine design for detected problems and adaptation design for the new problems (Johannesson and Perjons, 2014), which is omnipresent and benefits humans both in micro level and macro level in our lives. Therefore, Design Science is to design solutions in form of artifacts or systems to help people to overcome natural and societal problems, adapt to the new technological environment and facilitate their processes of solving problems.

"Technology is practical or useful, rather than being an end in itself, and it is embodied, as in implements or artifacts, rather than being solely conceptual (March and Smith, 1995)." To comprehensively grasp the complexity of a technical artifact, human element has to be addressed and reinforced in the interactions between the artifacts and their users. Though human element is the inherent dimension embedded in technology, it was subordinate to technological dimension because of the technology-driven design thinking's dominance in the field over the past decades by the view that primary interest in designing technology was to produce artifacts mainly on the basis of natural sciences. However, technology per se represents the combination of technical artifacts and what people do with them (Davis et al., 2014). The holistic perspective of Human Technology Interaction is significant when the design solutions are worked out for human-related problems and not just solutions for and within a certain technology (Niemelä et al., 2014).

With the complication of advanced technologies, especially the rapid upgrading of Information Technology, design in technology artifacts has to convert angles to the acceptance and user experience on human dimension, for single-mindedness on artifacts' technology dimension cannot cater to people's expectation on the improvement of life satisfaction. Considering the great influences of technology artifacts on human being, researchers in Design Science have to realize that they are not only designing technological artifacts but also designing different ways for people to live their everyday lives (Saariluoma et al., 2016). Technology is increasingly something "we live with, not simply something we use" (Niemelä et al., 2014). Design Science should put emphasis on how to better serve people and design a better way people live in instead of only designing things workable.

2.2 Design Science in Information System (IS)

Design Science is applicable to every field related to human, and the discussions and research in Design Science within the Information Technology (IT) and Information System (IS) have increased in recent years, due to the fact that it is a necessary paradigm for IT research (Denning, 1997) and only by design science paradigms, can significant IT issues be resolved (Hevner, 2014). The types of challenges faced in the IS field require novel solutions, as requirements are often unstable and complex interactions often call upon cognitive and social skills in developing and communicating solutions (Hevner, 2010).

Design Science plays a key part in the development and management of information technologies and systems (Winograd, 1996), which is related to what IS researchers do, namely, information-technology artifacts' creation, application, evaluation and improvement (Hevner, 2014). Walls et al. (2004) argued that the widespread adoption of Design Science in IS research would lead to more impacts on practice. For instance, "Design Science creates and evaluates IT artifacts intended to solve identified organizational problems", which requires a rigorous process to conduct artifact design, involving problem's relevance analysis, solutions to the existing problem, research contributions, evaluations and reflections on the design (Hevner, 2010).

Owing to its widespread application in different fields, Design Science literature consists of a great many references based on specific relevant research-based knowledge, and among them, engineering takes up a large proportion, closely related to the targeting at the artifact production (Van Aken, 2005). Archer (1984) shaped six components of Design Science research in engineering, "programming, data collection and analysis synthesis of the objectives and analysis results, development, prototyping and documentation." Informed by prior knowledge on Design Science, researchers structured specific methodology in Information System. The research methodology in Design Science in IS functions as a road map for researchers to use Design Science as props for Information System research. Walls et al. (1992) proposed elements of "meta-requirement, kernel theories, design method, meta-design, testable design and process hypothesis" in researching Design Science in IS. The differentiation of "constructs, models, methods, and instantiations" is commonly accepted in this field (March and Smith, 1995): constructs refer to the meta models to specify problems; models meant the application of meta models to the process or work flow; methods are the guidance on how to solve problems; and instantiations are the integration of previous sections (March and Smith, 1995).

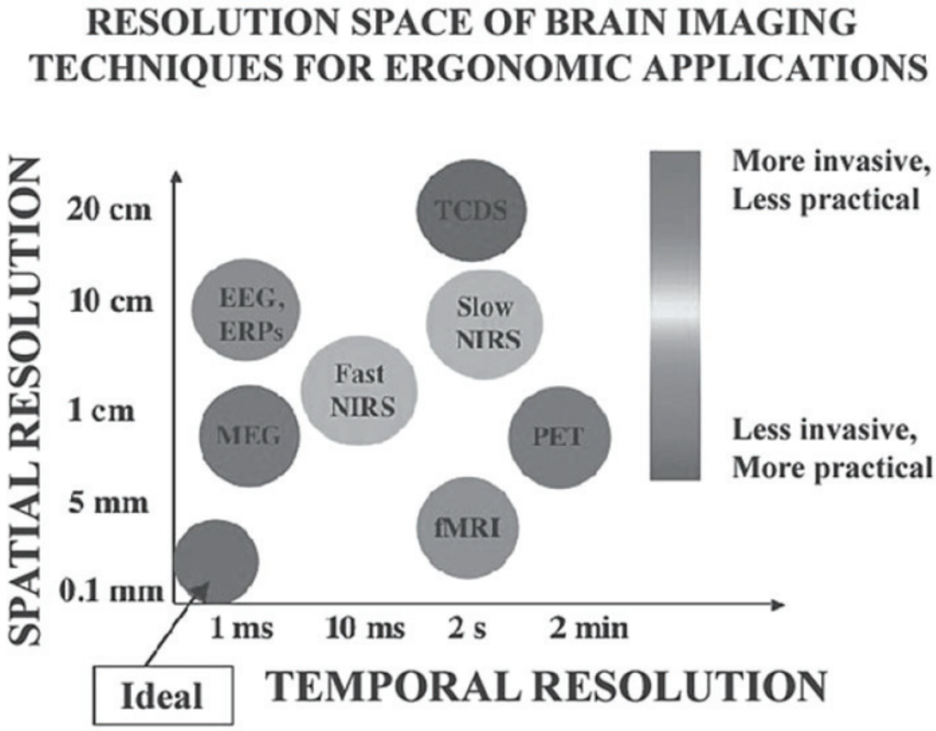
In relevant studies, the most cited literature is Hevner's (2010) paper "*Design Science Research in Information System*", presenting the guidelines in this field by "problem relevance, research rigor, design as a search process, design as an artifact, design evaluation, and research contributions." To design a methodology that would better serve as a common structure instead of stressing differences variations among various different research fields, Peffers et al. (2007) employed a consensus building approach to ensure Design Science research on well-accepted elements and achieved a flexible sequential framework, including "problem identification and motivation, define the objectives for a solution, demonstration, evaluation and communication," which established a common configuration validating Design Science research in IS and represented the general methodological guidelines on effective design research.

2.3 Neuroergonomics and Brain Computer Interfaces (BCI)

Most of the neuroscience studies are taking place in the laboratory settings instead of natural contexts so that most of the experimental conclusions cannot be applied to the authentic situations. Thanks to the improvement of brain imaging techniques, many brain imaging devices are portable or easy to be relocated, which makes it possible to move laboratory experiments to the natural settings to help people truly understand more about the relationships between cognitive processing mechanisms and behaviors. Additionally, rapid advancement of Information System provides researchers with more opportunities to widely use wireless connections and biosensors to acquire both physical and psychological information of the target people, laying the foundation for the application of neuroscience to the reality.

The application of neuroscience to Human Technology Interaction (HTI) research started with evaluating users' mental states by investigating the effects of task difficulty, mental effort or fatigue on changes in Electroencephalogram (EEG) patterns, related to other physiological indicators, such as skin conductance, heart rate or blood pressure, which is defined as Neuroergonomics (Müller-Putz, 2015). "If neuroscience has freed cognitive science from rigid functionalism, then Neuroergonomics may serve to liberate it from a disembodied existence devoid of context and provide it an anchor in the real world (Parasuraman and Rizzo, 2008)." Neuroergonomics took one step ahead of Design Science to move neuroscience into real life, but it itself has limitations by only pointing to Ergonomics, while design covers more applicable fields. In addition to brain imaging techniques, eye tracking system and facial recognition, the approaches to achieve Neuroergonomics study also include behavioral study and advanced Information System as well. For brain imaging techniques used in Neuroergonomics, different method has its specific advantages and disadvantages over others either in time / space resolution or the practicability in real life contexts (see detailed information in Fig. 1).

Apart from Neuroergonomics research, the research of Brain Computer Interfaces (BCI) also integrates neuroscience into its artifact design and has made great progress in its application to the real lives. The initial combination of neuroscience and BCI research witnessed the interfaces between the brain and the computer in standard BCI, like cochlear implant and prosthesis. Beyond standard BCI, Hybrid BCI is increasingly studied and utilized in different fields by further integrating with neuroscience research, including ongoing EEG and the analysis from other biosignals, such as electrocardiogram, electromyogram and so on, with signals coming from other input devices, like mouse or keyboard (Müller-Putz et al., 2015), which implies that hybrid BCI already has its multimodality advantages over other research methods to conduct higher-level complicated information processing research in real time.



Resolution space of brain imaging techniques for ergonomic application. Trade-offs between the criteria of the spatial resolution (y-axis) and temporal resolution (x-axis) of neuroimaging methods in measuring neuronal activity, as well as the relative noninvasiveness and ease of use of these methods in ergonomic applications (color code). EEG = electroencephalography; ERPs = event-related potentials; fMRI = functional magnetic resonance imaging; MEG = magnetoencephalography; NIRS = near-infrared spectroscopy; PET = positron emission tomography; TCDS = transcranial Doppler sonography.

Figure 1 Resolution space of brain imaging techniques for ergonomic applications (Parasuraman and Rizzo, 2008).

Some rewarding and productive research in Neuroergonomics and BCI, in recent two decades, was involved in the areas of aviation, driving, and virtual reality (Parasuraman and Rizzo, 2008) for their efficacy to examine the interactions among people's cognition, behaviors and their physical and psychological environment. However, emotion, as the most significant mediation to regulate the complicated relationships among cognition, behaviors and physical environment, has not been listed as the key research subject yet in the range. In view of the essential influences caused by emotion on people's life and work, combining with the in-depth investigations into human's cognitive processes against the background knowledge of neuroscience, an emotion design concept is proposed in this monograph to help more accurately measure mood states and provide effective solutions to emotional problems under the guidance of the theories in Design Science research.

2.4 The collaboration of Neuroscience and Design Science research

Incompletely understanding the needs of artifact users can result in inappropriately designed artifacts or artifacts that result in undesirable side effects (March and Smith, 1995), so, in order to build a desired technical artifact, Design Science researchers have to have a good command of the artifact users, including their cognitive processes in using the artifact and their corresponding emotional situations. Meanwhile, besides 'building', 'evaluation' is the other element Design Science researchers have to emphasize, which is terribly complex for it involves many aspects, such as the development of the criteria for the technical artifacts, the evaluation of environment in which the artifact operates, the relevant evaluation of the artifact users and the assessment of the artifact's performance. To solve the above-mentioned cognition-related or emotion-related problems and better evaluate related efficacy of the artifacts, it is possible currently for researchers to take advantage of the knowledge of newly emerged Neuroscience to present more valid and reliable evidence via brain imaging techniques. With the development of cognitive science, access to brain data has provided more chances to investigate into the cognitive and emotional processes in inference and decision-making, giving rise to the joint research of neuroscience and Design Science Research in Information System. "We have reached a tipping point where the fields of neuroscience and Information System are able to collaborate to identify and frame fundamental questions about the relationships between creativity, design, innovation and research (Hevner, 2014)."

The existing neuroscience literature explored close correlations between the functions of brain regions or brainwaves or frequency oscillations and specific cognitive processes, such as emotion, creativity, insight, design, communication, and so on (Dietrich, 2004), which are also discussed in Design Science research in Information System by interrelating with the basic elements in its research methodology, "problem relevance, research rigor, solutions to problems, artifact design, design evaluation and reflections". Hence, the findings of Neuroscience research can meet the demand of those elements and the collaboration of neuroscience and Design Science research in Information system will help these two intertwined research fields produce more fruitful results.

Neuroscience research is endowed with triple functions due to its research content and particular research method, including knowledge-based function, research-tool function and evaluation-method function, so it can provide more objective, valid and reliable evidence by brain imaging techniques, which is quite useful and effective to help to detect problem relevance, establish the rules for research rigor and explore the solutions to the problem. Furthermore, neuroscience research can also act as the research tool to unbiasedly and objectively evaluate both the efficacy of the technical artifact and the users' emotional conditions. Last but not least, the reflections on the usage of the designed artifact, on the other way round, examined the validity and reliability of the relevant neuroscience research results, forming a loop to improve both neuroscience research and Design Science research in Information System (see Fig. 2).

"The primary argument for the use of neurobiological approaches in Design Science research is the IT artifact design - and, ultimately, Human Computer Interaction (HCI) in general - may significantly benefit from neuroscience theories, concepts, methods, and data (Brocke and Léger, 2013)." In this study, neuroscience is not thought of as a valuable complement to the conventional design, but as a major design reference for building IT artifacts instead. Cognitive science study should not limit itself to the study of mental processes in isolation, and it should create the relevant artifacts and technologies instead to further develop a virtuous circle, like, study – create / design - evaluate- restudy – recreate / redesign - reevaluate, to continue the relevant research and conduct more objective and more effective designs.

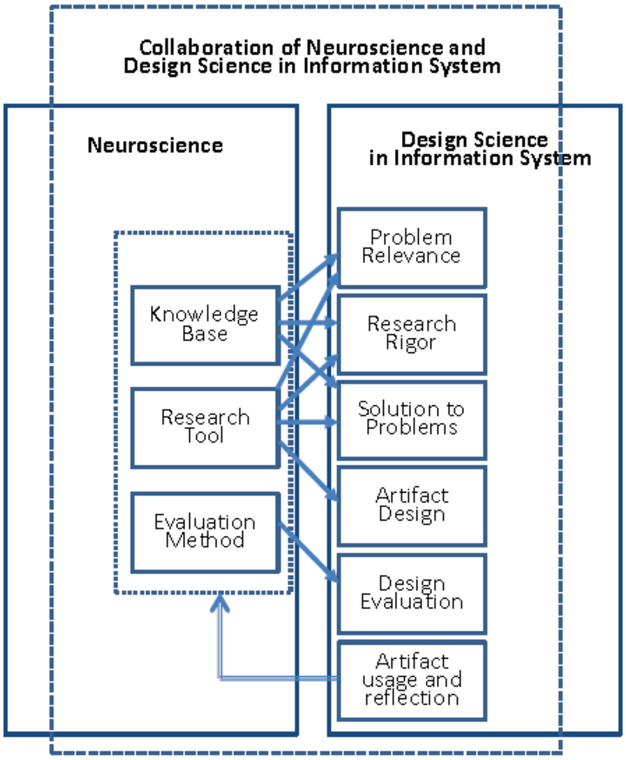


Figure 2 Collaboration of Neuroscience and Design Science in Information System

3 LIFE-BASED DESIGN

3.1 Human-Driven Design

Human-Driven Design was put forward by Brand and Schwittay (2006) to supplement approaches to the research of Information Computer Technology by considering human dimensions, such as local practices, participatory design processes, social-cultural contexts and political conditions. It puts stress on the early stages of design, being greatly future-oriented by integrating more human values, human needs and human factors into the design, especially the design of the interaction between humans and computer systems, and targets at facilitating innovative designs for the sustainable development in society and improving people's life satisfaction (Niemelä et al., 2014).

Human-Driven Design not only focuses on the realization of the design of technical artifacts, but also includes more human and societal elements by involving stakeholders in the design and taking the emerging helpful technologies into consideration. It was mainly built on the design frameworks of "Human-Centered Design, Participatory Design and Value Sensitive Design" to attempt to exert influences on "ambient intelligence, ubiquitous computing, autonomous systems, emotional computing, service robotics and convergence of Information Computer Technologies and other technologies (Niemelä et al., 2014)." It shares many ideas with above-mentioned theories to emphasize to satisfy the physical and psychological needs of human users to the largest extent by really immersing stakeholders in the observing and brainstorming the problems via integrating technological tools to determine the solution.

3.2 Life-Based Design and Form-of-Life analysis on people with negative mood

3.2.1 The basic understandings of Life-Based Design

For a long period of time, technical design has been much more product-oriented than human-oriented. However, technologies, combining human actions with technical artifacts or systems, are ultimately designed for people to enhance the quality of life (Leikas, 2009; Saariluoma and Leikas, 2010). Thus, everyday experiences of people and their relevant social, cultural and mental aspects, against the contexts of technical artifacts, should be taken into account in the design practice (Saariluoma et al., 2016). Based on Human-Centered Design and Human-Driven Design, Life-Based Design involves a multi-dimensional design theory putting emphasis on the significance of comprehensively understanding people's lives, including forms of life, values and circumstances as the foundation underlying design ideas and design concepts, to ensure that the artifacts start from people and better satisfy people's needs (Leikas et al., 2013).

Investigating the structure of actions relevant to particular form of life is the core tool used in Life-Based Design, for exposing relevant differences between different life settings can provide a precise yet elastic enough concept to define the target (Saariluoma et al., 2016). Although people can take part in a good deal of different forms of life, their regularities reflect their states of being, hidden values and different moods in real lives. In a sense, "participating in a form of life is not necessarily a voluntary choice, and an individual may be 'thrown' into it" (Saariluoma et al., 2016) for some reason, which is decided by their physical and psychological states and their living states, concerning home environment, social development and cultural implications.

Diversified aspects connected to people and their living states constitute human life sciences, presented by Form-of-Life, which, from a macro point of view, consists of three essential factors: biological factor, psychological factor and socio-cultural factor (see Figs. 3 and 4). Despite the fact that all these three factors are greatly important in Form-of-Life analysis, the biological factor, a precondition of the existence of humans, ranks as a primary factor being investigated, including the investigations in ecology (e.g., Berkes and Turner, 2006), human ethology (Eible-Eibesfeldt, 1989), physiology, anatomy and neuroscience (Corr, 2006). The second factor of human life sciences presented by Form-of-Life is the psychological factor, relating with perceptions, emotions and behaviors in different social contexts, like family, education, philosophy and psychology. The third factor is about sociology and culture, covering a number of disciplines, such as anthropology, ethnography, gerontology, linguistics, semiotics, history, art, literature, and so on (see Fig. 4). These fundamental and intercorrelated factors are elementary in understanding how and why people take part in particular form of life, displaying the basic structures of Form-of-Life. Technology design aiming at serving human should be built on the holistic and objective investigations into Form-of-Life, and then the technical artifact is possible to really satisfy the needs of users. Therefore, the Form-of-Life analysis should precede every experimental process, concept design or technology innovation to propose more practical, valid and concrete technical artifact designs to enhance the well-being of humans.

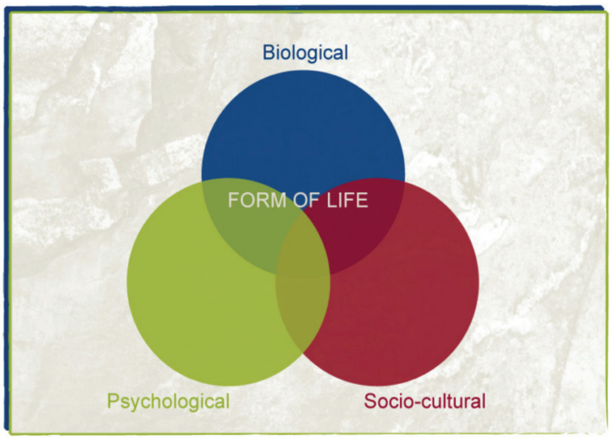


Figure 3 Essential factors of Form-of-Life (Saariluoma et al., 2016)

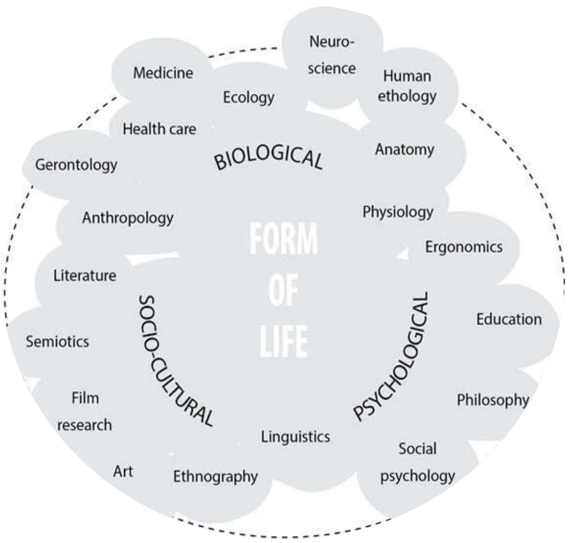


Figure 4 The palette of human life sciences presented by Form-of-Life (Saariluoma et al., 2016)

With the rapid updating of science and technology, we need to keep close pace with the times and continuously inject the vitality into design theories to enrich the methodological processes. The past investigations into the Form-of-Life were mostly achieved by surveys and interviews, which, to some extent, cannot objectively reflect the reality due to the lag in recording method, and furthermore, those closely involved cannot see clearly, so more objective methods of observing and analyzing Form-of-Life is needed to assist people in figuring out their true states of mind. The newly developing neuroscience research, resorting to its sophisticated brain imaging method, can fill the gap, providing more insights into the cognitive processes by exploring different features in brain signals and functional brain regions to reflect with validity on the biological factor changes related to the brain in the Form-of-Life analysis.

3.2.2 Form-of-Life analysis on people with negative mood

In daily life, people often talk about someone is in a good mood or a bad mood, which is actually an emotional state over a relatively long period of time, not very specific or intense like emotions and affects. The mood states are significantly correlated with the well-being of people, and thus, to enhance people’s well-being or to improve their good mood is the priority to be taken into consideration in technical artifact design process. Good mood, or positive mood, reflects the extent to which one experiences more positive states, such as joy, interest and confidence. Bad mood, or negative mood, concerning depression, anxiety, stress, poor self-respect, and low self-confidence, can affect an individual’s judgement and perception of objects and events (Laceulle et al., 2015), resulting in the misinterpretation of the surrounding world. Up to 25% of the population experience at least one episode of depression in their lifetime (Kessler et al., 2001), with up to 30% of young people experiencing mild subclinical depressive symptoms by 18 years old (Lewinsohn et al., 1993).

Among various signs of negative mood mentioned above, depression is listed as the most damaging and far-ranging, affecting 350 million people worldwide (WHO, 2012), and investigators projected that by the year 2020, depression will impose the second greatest burden of ill health, very close behind the top cause, ischemic heart disease (Leahy, 2002). Depression not only refers to the clinical disease which often prevents people from living a normal life, but also refers to a feeling of unhappiness or sadness that makes people think there is no hope for the future, which sometimes also happens on normal people. All individuals have mood swings and normal individuals may have “blue” hours and “blue” days, and the episodes of low mood or of feeling blue experienced by normal individuals are similar in a number of ways to the clinical states of depression (Beck and Alford, 2009), so healthy people are probably trapped into depressive mood which seriously impacts their mental health. For this reason, negative mood, depression in particular, is the target problem I attempt to solve in this monograph.

Conducting research under the guidance of Life-Based Design, above all, I made a Form-of-Life analysis on people with depression to illustrate a holistic approach preceding the proposal of the following emotion design concepts.

3.2.2.1 Biological Factor

Bad sleep, overeating decreased appetite, low energy, fatigue, decreased interest in pleasurable stimuli etc. will affect the biological functions of people with depression. Tracing the origins of depression, though epidemiologic studies show that roughly 40-50% of the risk for depression is genetic (Sanders et al., 1999), "nongenetic factors as diverse stress and emotional trauma, viral infections, and even stochastic processes during brain development have been implicated in depression (Akiskal, 2000)," which reveals the close correlations between depression and brain. Hence, to explore the biological factor in Form-of-Life analysis, brain is the key.

Drevets (2001) demonstrated the changes in some brain areas were greatly correlated with depression, such as in "prefrontal and cingulate cortex, hippocampus, striatum, amygdala and thalamus," and anatomic studies of brains of people with depressive mood obtained at autopsy also reported abnormalities in many of these brain regions (Zhu et al., 1999). In addition, Nestler et al. (2002) indicated that particular brain regions were connected to the mediation of different elements of depression and different brain areas operated in a series of highly interacting parallel circuit, formulating a neural circuitry involved in depression (see Fig. 5). First of all, from the perspective of brain areas, hippocampus and frontal areas had been closely connected to depression, and nucleus accumbens, amygdala and some other subcortical structures underlying reward, fear and motivation were also implicated in it. What's more, from the perspective of the linkups among relevant brain regions, the ventral tegmental area provided dopaminergic input to the nucleus accumbens, amygdala, prefrontal areas and other limbic structures, and norepinephrine (from the locus coeruleus) and serotonin (from the dorsal raphe and other raphe nuclei) innervated all relevant brain regions. Additionally, the strong connections between the hypothalamus and the ventral tegmental area - nucleus accumbens pathway exerted great functions in the neural circuitry of depression; dysregulation of the hippocampus and hypothalamic-pituitary-adrenal axis, impairment of neurotrophic mechanisms and impairment of brain reward pathway were found in connection with people with depression.

With respect to predicting a long-term course of depression, Beck and Alford (2009) indicated that neuroendocrinology studies found the disturbances in the hypothalamic-pituitary-adrenocortical axis in chronic depression were similar to those in nonchronic types. Among the positive biological findings that were consistently associated with depression, there had been excessive levels of steroids, sodium retention and changes in sleep EEG patterns; dexamethasone nonsupression of plasma cortisol had been suggested as a marker, although the same effects had been induced experimentally by sleep deprivation and dietary fasting (Beck and Alford, 2009).

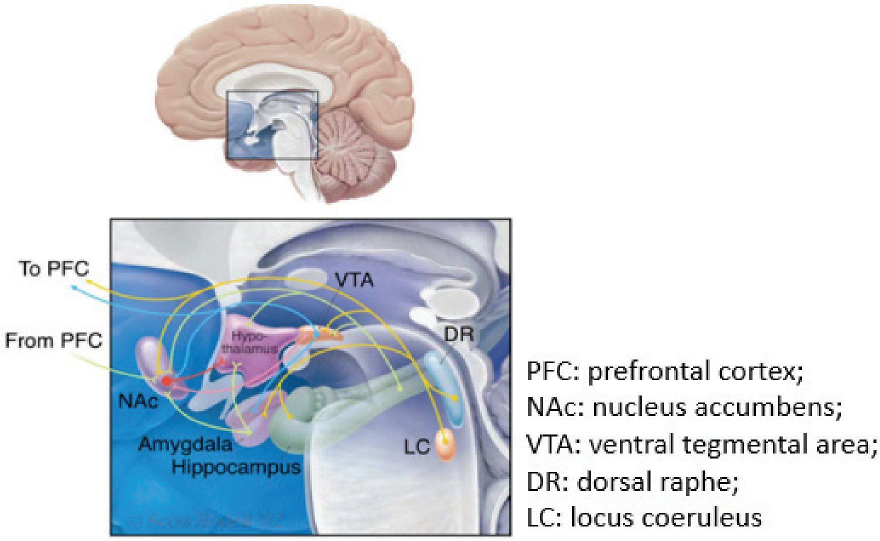


Figure 5 Neural Circuitry of Depression (Nestler et al., 2002).

Therefore, in terms of biological factor, to find an effective way to conquer the depression, we have to come up with an innovative design concept with proper interventions against current technological background to mediate the neural circuitry to positively simulate brain activities in prefrontal cortex, reward areas and limbic structures. Humor, as an effective 'medicine' and a frequently used intervention method, will be comprehensively studied in the later content to illustrate its efficacy and applicability in resolving biological factor problems related to brain among people with depression.

3.2.2.2 Psychological Factor

In J.S. Beck's (1995) analysis, people with depression often have "if-then" statements (for example, "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"). They also have difficulties in expressing the nature of reality without considerable outside help because of their "deep cognitive structure". Also, they are unwilling or unable to examine the evidence against their validity, for they consciously think about them at all as "just the way things are (Leahy, 2002)." The chief complaints of depressive people from the perspective of psychological factor are like: "I have nothing to look forward to"; "afraid to be alone"; "no interest"; "can't remember anything"; "get discouraged and hurt"; "black moods and blind rages"; "I am doing such stupid things"; "I am all mixed up"; "very unhappy at time"; "brooded around the house" (Beck and Alford, 2009).

Furthermore, Rissanen (2015) indicated that several elements were greatly distorted in the course of psychological cognition of people with depressive mood, such as negative automatic thoughts, beliefs, rules for living and core beliefs in daily life (see Table 1). And their typical inner monologue is to deny themselves in every aspect with negative emotion and beliefs, such as low self-evaluations, distortions of the body image and negative expectations: prone to hold themselves responsible for any difficulties or problems they encounter and indecisive (Beck and Alford, 2009). Meanwhile, depressed people are more sensitive to failure than nondepressed people. They reacted with significantly greater pessimism and a lower level of aspiration, tending to distort their experiences in an idiosyncratic way: they misinterpreted specific events in terms of failure, deprivation or rejection, inclining to make negative predictions on their future (Beck and Alford, 2009).

Table 1 Example of profile of a depressive subject (Rissanen, 2015)

Elements	Cognitive profile
Negative automatic thoughts	This is not good enough. There is no point in trying. Life is just too difficult.
Beliefs	I have got to give it my best. I am a failure if I don't achieve perfection.
Rules for living	You can do things perfectly or not at all. No point in starting if you can't you can't finish it to perfection. No rest before the work is done.
Core beliefs	I am not good enough; I am incompetent.

In terms of psychological factor in Form-of-Life analysis, to heal people with depression, we need to effectively convert their defective and partial thoughts. A better way is to use appropriate intervention tool with positive stimuli to change people's way of thinking and shift the angles of viewing the problems they are facing. Humor, which needs the transforming of the angles to resolve the inconsistencies to reach the stage of mirth, regarded as a very useful tool to help people detect novel insights, will play a significant role in changing the way of thinking of people with depressive mood if it is used in a design concept.

3.2.2.3 Social Factor

Distorted mentality is deeply rooted in the social factors. Some unhappy personal experiences, severe stress from the study and work, negative influences from violence, neglect or poverty may make people vulnerable to depressive mood. The ordinary states of them are the impressive feelings of sadness or marked loss of interests or pleasure in social activities, with sense of worthlessness or inappropriate guilt. Research of day-to-day social interactions revealed that, compared with nondepressed participants, depressed participants found their interactions to be "less enjoyable and less intimate, and they felt less influence over their interactions (Nezlek et al., 2000)." Besides, they usually had more intense responses towards the negative interactions with people. Some studies provided the indications that depression may sensitize people to everyday experiences of both social rejection and social acceptance (Steger, 2009). With decreasing in interpersonal relationship outside the family, a study (Forgas, 1984) collected the evidence that people with depression were critical about surrounding happenings, showing excessive mood fluctuation tendency. Meanwhile, they were closely connected with more frequent online social interactions, which, in turn, had negative effects on the usage outcomes associated with the internet use (Caplan, 2003).

Thus, from the angle of social factor in Form-of-Life analysis, the habitual way of communication in interpersonal relationships has to be improved to increase their opportunities to socialize with people outside their limited social networks. Humor, a widely accepted way of bettering interpersonal relationships, deserves more attention in designing artifacts to help depressed people be involved in more social interactions and build up their confidence in communicating with people around by their particular way of humor.

In short, the Form-of-Life analysis on people with depression requires an effective intervention tool in the design concept to stimulate the activities of specific brain regions responsible for mood regulation, helping to shift defective habitual way of thinking and improve the interpersonal relationships. Taking these elements into account, humor appreciation is an optimal selection to fulfill the goals due to the overlapping brain regions between humorous stimuli and depressive emotion. Thus, to present the comprehensive potential impacts on future artifact users, prior to the proposal of the design concept, humor, including its concept, its theories, its relevant factors, its cognitive process and its influences on both physical health and psychological health, has to be thoroughly investigated. Among these relevant ingredients, cognitive processing mechanism is the key point for its fundamental and decisive role in this design concept.

4 THE BASES OF HUMOR

4.1 Conceptual bases

4.1.1 What is humor?

Humor is ubiquitous, and the smile or laughter caused by humor are universal phenomena in society, existing everywhere in the world and happening in all individuals in almost every occasion (Apte, 1985) and in all stages over a lifespan, including infancy, childhood, adulthood and old age. Humor and laughter is one of human being's instincts for survival and the neural circuits of laughter in the brain come into being when a person is at birth, gradually developing into the neural circuits of humor appreciation running through different life phases (Li et al., 2017). Humor plays a very critical role in various social contexts across both biological and cultural development and has evolved into a multifunctional and commonly used communication pattern exerting great influences on both society (Martin, 2010) and individuals, involving their psychological, cognitive, emotional, behavioral and physiological aspects.

The definitions of humor differ according to researchers' different research focuses. There is no finishing definition or an "all-encompassing measurement tool" covering everything humor involves (Samson, 2008). Researchers (for example, Ruch, 1998a) dated back to the origin of the word of humor, which was referred to as "bodily fluids" in ancient Greece and believed to be able to interfere with both physical and mental conditions, and as time went on, humor, gradually being used to imply mood or emotion, "eventually progressed into a connotation of wittiness, funniness and laughableness, although not necessarily in a benevolent sense (Martin, 2010)." In a way, the core of the experience of humor appreciation is to perceive the funniness of something. "The Freedom of Wit and Humor" (Shaftesbury, 1711) is the first written record using the word "humor" with the meaning of funniness similar to what we understand nowadays (Morreall, 2008a), and this usage was widely spread since then, with funniness-rating the most commonly employed reference method in humor-related studies (Raskin, 2008).

Cambridge Dictionary[1] contains two meanings when referring to humor, the first is "the ability to find things funny, or the quality of being funny", and the second is "the state of your feelings". Analogically, Oxford dictionary[2] also defines humor from two aspects: one is "the quality of being amusing or comic" and the other is "a mood or state of mind". On balance, looking beyond the surface meanings the dictionaries provide, the explanations of humor in two dictionaries mainly cover three components: social component, cognitive component and affective component, uncovering the in-depth implications of humor as a concept.

4.1.1.1 Cognitive component

"To find things funny" is to understand the funniness aspect of the things, which involves a complicated high-level mental process. For one thing, from the angle of people who find things funny, we have to receive the information from the outer world, conducting simultaneous, unconscious and automatic search in our memories, integrate the meanings of the words and analyze the meanings in an innovative way to catch the laughing point. People's cognitive capacities to comprehend hidden conflicting things, being creative to comprehend complex meanings, and perceive the funny side of the integration beyond surface meanings are the essentials underlying humor. For the other thing, from the angle of funny things, "the quality of being funny, amusing or comic" implies the cognitive nature of things, which basically refers to the incorporation of two originally conflicting things into something logical and understandable, involving detailed conflicting, their common-sense recognition and innovative integration. Hence, cognitive component is by nature embedded in humor, critical to comprehend the in-depth conceptual meaning of humor.

Early in 1770s, the Scottish poet and philosopher, James Beattie (1776a), proposed that "laughter arises from the view of two or more inconsistent, unsuitable or incongruous parts or circumstances considered as united in a complex object or as acquiring a sort of mutual relation from the peculiar manner in which the mind takes notice of them." Those are the very early revealings on humor in terms of its cognitive component. Then the cognitive component of humor came to the foregrounding by the accounts of some other philosophers, such as Kant and Schopenhauer (López and Vaid, 2017), focusing on the cognitive experiences about resolving inconsistent things to result in the feelings of mirth or joy.

Facing the same humorous stimuli, different people have different responses, relating to the fact whether the reintegration of two basically conflicting things is logical or identifiable, and whether the individual's cognitive abilities can reach the level in which one can successfully process the joke. Further speaking, the cognitive component in humor can be understood

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[1] http://dictionary.cambridge.org/dictionary/english/humor
[2] https://en.oxforddictionaries. com/definition/humor

from two angles: the cognitive capacities of people, which is evidently influenced by a number of factors, such as age, IQ and gender, and the cognitive structure of humorous stimulus, involving the incongruence between the expectations and the actual results. The degree of the incongruity and its corresponding resolution were regarded as the crucial ingredients of humor formation (Suls, 1972).

4.1.1.2 Social component

"Funny" or "amusing or comic" things have a broad umbrella meaning that covers all sources of laughter: verbal or nonverbal jokes, comedies, sitcoms, satires, teasings and ridicules (Martin, 2008), and the occurrence of all these sources hinge on some certain social contexts. Without social contexts, there are no more social norms or so-called appropriate social behaviors and people will have no standards to judge the congruence or incongruence between things. As a result, there will be no more humor sources in interpersonal communications, and even the communications among people will not exist. Thus, social component can be concluded as the fundamental component to see through the concept of humor.

From its origin, humor is a social phenomenon and it may take place in any social situations, implicating certain human relations in society among individuals, as we cannot tickle ourselves (Fine, 1983). No matter what the type of humor is, they all occur in the course of social interactions among people. Even when people watch comedies, slapsticks, cartoons or humorous stimuli in an experiment, they naturally and unconsciously put themselves in a pseudo interaction context involved the communication with other people. Moreover, the humorous statements are formed on the basis of social and cultural norms, and unique to particular social and cultural contexts, so the relevant content people having humorous remarks on are mostly nuclear to the social issues, cultural values and moral standards in a social organization (Kuipers, 2008). Therefore, the specific social contexts, covering various aspects, such as the detailed time, place, in what manner and to whom the humor occurs, have great impacts on how the humor takes effects and what the humor implies (Oring, 2008).

Humor is social not only "in its origin, in its occurrence, but also in its functions and in its effects" (Hertzler, 1970), which makes humor a very rewarding topic to study. In the course of biological and cultural development of human history, humor has played various social roles (Martin, 2010), by either improving social cohesion inside a group, or precluding people from entering it. Humor also helps to provide effective interventions or solutions aiming at various negative emotions, bringing about positive influences on the shaping of social values and social behaviors.

4.1.1.3 Affective component

People's response to humor is not merely reflected in the comprehension level, but also in the emotion level, presented in a unique feeling of mirth occurring with varying degrees of intensity (Martin, 2010). "The state of your feelings" or "a mood or state of mind" in defining humor in dictionaries manifests the evocation of an emotional response or mirth stimulated by the comprehension of funny or amusing things. The affective nature of humor has been in evidence in the brain imaging experiments conducted by Goel and Dolan (2001): successful jokes contain both a cognitive processing and a subsequent emotional reaction of mirth, which are necessary elements to the generation of humor, reflecting in the activation in medial ventral prefrontal cortex, a brain area concerning reward processing. Similarly, other investigations also indicated that humor stimuli can elicit the activations in the reward system in the brain due to the corresponding emotion response (Mobbs et al., 2003), which shares similar brain circuits with emotional states related with the enjoyable activities, explaining why people would like to voluntarily seek humorous resources by themselves. Thus, affective component is the most prominent component in conceptualizing humor.

Three components built in the concept of humor are not in isolation but interwoven, mutually influencing each other and collaboratively showing the complexity of humor. Every single component underlying humor can be extended to a great number of possibilities within the range. In this monograph, the emphases are mainly put on the cognitive component and affective component of humor, both related to the biological factors in human being or the brain mechanism in particular. Through deep investigations into humor processing mechanism and the relevant applications into realities by using advanced technology, researchers may make better use of the positive effects of humor and seek out the effective solutions to enhance people's positive mood.

4.1.2 Why is humor worth investigating?

4.1.2.1 Humor benefits people as individuals

Humorous utterance takes its specific effects in various aspects of human-being, across different cultures and in different situations, so much so that humor, viewed as an ability, a virtue / character strength, or an aesthetic perception (Raskin, 2008), has been greatly valued by people. In terms of modern social values, the importance of sense of humor is greatly attached to personal assessment: people who have sense of humor are regarded as the ones who have more abilities dealing with stress and having harmonious relations with others, and even have more healthy conditions physically and psychologically (Lefcourt, 2001).

Underlying the interpersonal mechanism, the usage of humor in social communications increases individuals' social supports from people who are influenced by their humor (Martin, 2010). Humor is not only an indication showing the close relationship among people who use it, but also an effective tool to distance people from others to strengthen the social network which each individual belongs to. When people meet for the first time or something embarrassing happens, humor helps to gather people from different social class or status together and produce the feeling of common "conspiracy" (Kuipers, 2008). A number of studies suggested that the sense of humor may improve the relations between couples, friends, workmates etc. For instance, in real communications, it is inevitable to have some implicit and inconvenient messages that are difficult to express in direct ways, so, under this circumstance, humor can be utilized to convey the connotative meanings in an indirect and subtle way (Mulkay, 1988). For another example, in complaining, the humorous complaints benefit people by making complaints seem more positive, which is less likely to elicit redress or sympathy from others than non-humorous complaints (McGraw et al., 2014). Hence, humor provides people with a special, acceptable and unharmful way, different from common communicative ways, to convey contradictions, solve problems and increase positive feelings among people in dealing with diversified relationships (Martin, 2008).

Humor is both useful and meaningful to be used as a tool to set up the foundation for practical and effective coping strategy (O'Connell, 1976). Because of the analysis on conflicting ideas or situations in a surprising or unexpected manner in humor appreciation, people are more likely to view things from different and creative angles, by which people can build an alternative mechanism to cope with adversity, which is in line with Freudian (1928) ideas: humor can be used as an effective and healthy defense mechanism. A quantity of studies showed that the humorous way of life has profound implications for decreasing life pressure, distancing individuals from devastating consequences (Freud, 1928). The capabilities to realize that many problems that can be analyzed and solved in a humorous way can help people handle things more effectively and efficiently due to more flexible ideas deriving from innovative perspectives, which keeps people away from stressful situations and improve their confidence to conquer difficulties in life (Martin and Lefcourt, 1983). What's more, humor provides individuals with recreation sources to make them refresh themselves from daily life stress so people can also enhance their positive mood by enjoying the mirth brought by humor to gain more courage and confidence to overcome the problems. "Individuals engaging in activities that require persistence also benefit from exposure to humor (Cheng and Wang, 2015)." In short, during the course of appreciating humor, individuals profit from both the creative problem-solving methods and positive mood by transferring their attention to the funniness side of the problem, increasing the possibilities of coping options and helping to construct various resources, related with physical, intellectual and social aspects, to tackle problems (Martin, 2010).

Additionally, humor can be used as physical defense mechanism as well. Humor benefits people physically because laughter can stimulate the respiratory, musculoskeletal, vocal and cardiovascular activities (Martin, 2008). With the development of brain imaging techniques, researchers found that humor also benefited brain development by stimulating the activities in specific brain areas to arouse corresponding positive emotion. For example, growing old with age reduces people's abilities to acquire things, detrimental to the memory maintenance, but "laughter caused by humor can decrease stress and cortisol to avoid the harmful effects of the long-term cortisol release on learning and memory closely correlated with hippocampus (Bains, 2014)."

4.1.2.2 Humor benefits people in group

Apart from the profound meanings on individuals, humor has great effects on group organization and operation. That is why a great number of humor researches have been conducted to relate with different fields, such as workplaces, education, business, politics, health care and so on. Inside group, humor plays a significant part in promoting interpersonal communications, setting up the harmonious connections, improving the close relationships with leaders, distancing the group from external people and strengthening the obedience of members (Fine and Soucey, 2005). The mirth caused by humor is linked with responsive laughter, which can help to identify members belonging to the same group, send hidden signals to the people who are willing to join in and pay back cooperative efforts to boost the internal cohesion (Martin, 2010). Moreover, the mirth caused by humor can also be contagious to the people around, creating harmonious atmosphere, enhancing positive emotions among group members and cheering up the team morale in face of problems.

In workplaces, humor plays a vital role in reinforcing the commonly organizational values, uniting team members together, establishing organizational cultures and even conceptualizing the supervision model (Morreall, 2008b). Successful humor bears the potential to provide remedies to various problems to contribute to the overall working efficiency by releasing staff's pressure, promote healthy work environment and increase satisfaction feelings between superiors and subordinates, resulting in positive effects on productivity, viability, effectiveness and personal development (Romero and Pescosolido, 2008). Furthermore, by presenting a more harmonious way to settle the contradictions, humor also contributes to the group cohesion by consolidating the common values and setting up the agreed regulations for inconsistent opinions. "Through enabling members to shift between unifying and differentiating remarks, humor allowed members to maintain unity when they are in the face of diversity" (Meyer, 1997). On the whole, there are mainly three advantages that people can benefit from humor in the working places: "promotion of health conditions, flexible thinking, and smooth social connections (Morreall, 1991)."

Humor also has irreplaceable and unique influences on education. Humorous teachers are always more welcome by students and humorous lessons are more vivid and memorable, giving rise to good teaching effects. Because of the angle transfer, students gradually learn to analyze problems from different angles in the course of humor appreciation, which leads to the increase of their abilities in critical thinking. With the teaching content being presented in a more interesting way, the attention of students is greatly drawn to the lectures, which brings about a series of chain reactions, such as the release of the study pressure, the formation of good teacher-student relationships and the enhancement of collective spirit, providing underachievers with more opportunities to participate in activities (Morreall, 2008b). Thus, taking proper advantage of humor will build up the harmonious and open atmosphere to improve both class teaching effects and learning effects by more positive inter-evaluations between teachers and students, greater enjoyment of the teaching content, and greater learning outcomes (Martin, 2010). Besides, when talking about some sensitive topics in class, humor serves to be a particularly effective tool for teachers (Johnson, 1990). Similarly, humor can also help handle some negative attitudes and anxieties in academic learning (Berk and Nanda, 1998). Students' social and intellectual capabilities can also be improved by the regular and appropriate use of humor (Lovorn, 2008).

In comparison to strengthening the unity inside a group, humor also plays a part in excluding people who have divergent ideas from others. In this sense, humor is a method of managing, as "mocking nonconforming behavior can reinforce power and status differences and suppress undesired actions (Martin, 2010)." Particularly in politics, humor is employed in political conflicts to effectively attack political opponents by humorous ridicules and teases (Kuipers, 2008).

In health care, the usage of humor with purpose in a natural way increases the mutual understandings between doctors and patients to ease their tensions. At the same time, the positive mood elicited by humor serves to help patients overcome the disease, release the nervousness before surgeries and relieve the pain. Considering the positive effects brought by humor on both physiology and psychology among patients, researchers developed humor therapy as one of cognitive therapies to alleviate their sufferings.

In a nutshell, people can gain numerous benefits from humor's application to both groups and individuals because of the joint interactions among its cognitive, affective and social components, which provides people with opportunities to view things from different perspectives instead of the single and fixed perspective, maintaining their positive mood and smoothing interpersonal relationships.

4.2 Theoretical bases

Humor is such a complicated phenomenon that a great number of theories, involving various elements of humor, have been researched and developed. In 1920s, researchers summed up eighty-eight different theories on humor and, nowadays, there are even more wording to elaborate on it (Samson, 2008). "Most of the humor theories ever proposed are actually mixed theories and many contemporary researchers believe that humor in its totality is too huge and too multiform a phenomenon to be incorporated into a single integrated theory (Krikmann, 2006)." However, different theories of humor extract the features of the humor in different circumstances, making appropriate supplements to each other rather than conflicting with each other.

'Humor' did not carry the meanings of funniness, but laughter instead, until the 18th century, and then, the Superiority Theory was developed as the only approved theory for quite a long period, followed by other two theories: the Relief Theory and the Incongruity Theory, with these three theories being distinguished as classic humor theories afterwards (Morreall, 2008a). In 1980s, on the basis of the development of the Incongruity Theory and cognitive linguistics, Semantic-Script Theory of Humor was proposed (Raskin, 1985) and much attention in this field was paid to it. In this monograph, humor-related theories are roughly grouped into two categories by putting emphasis either on the cognitive processing of humor or on the functions of humor as a social phenomenon. One category is about cognitive theories of humor, including the Incongruity Theory and the Script-Based Semantic Theory (further developed into General Theory of Verbal Humor), and the other category is about the functional theories of humor, including the Superiority Theory and Relief Theory.

4.2.1 Cognitive theories of humor

Though different theories place different stress on different components of humor, recent decades in humor studies saw more discussions in the cognitive processes of humor, rendering cognitive theories of humor very popular. These cognitive theories have some commonalities in agreeing that "the detection or perception of an incongruity – a disproportion, disagreement or discrepancy between elements in the joke – forms the basis of any kind of humorous experience (Suls, 1972; Shultz, 1976; McGhee, 1979)."

4.2.1.1 Incongruity Theory

In the 18th century, Beattie (1776b) indicated that laughter occurred when two or more divergent or conflicting circumstances were integrated into one intricate aggregation. Then in the 19th century, Schopenhauer (1788-1860) suggested that the abrupt understandings on the incongruity between the inherent concept and the actual happenings elicited laughter. He stated, "the cause of laughter in every case is simply the sudden perception of the incongruity between a concept and the real objects which have been thought through it in some relation, and laughter itself is just the expression of this incongruity…. All laughter then is occasioned by a paradox (Piddington, 1933)."Afterwards, Koestler (1964) further explained the incongruity was the core of humor, who coined a term 'bisociation', signifying 'the juxtaposition' of two normally incongruous frames of references or the discovery of various analogies implicit in concepts normally considered remote from each other. By experiments, Thomas Shultz (1972) provided a good deal of supports for the general proposition that the structure of humor was characterized by the incongruity and resolution, which, different from previous versions of incongruity theories, laid stress on the resolution. He exemplified it by jokes: the incongruity and the resolution were the structural aspects of a joke, embodied in the inconsistent relationship between joke's setup and its punchline. Without resolution, the unresolvable incongruity was not humor but nonsense.

Similar to Shultz, Jerry Suls (1972), based on an incongruity-resolution model, came up with a two-stage model of humor comprehension, resembling a problem-solving process (see Fig. 6). When reading a story or a cartoon, we firstly get the knowledge of its development background with our own predictions towards the outcome. If the ending is the same with what we expected, there will be no surprise and no laughter as well; if the ending is not what we expected, we will feel surprised and then we have to find the rule that makes sense. Once we find out the rule, laughter occurs. Otherwise, the puzzlement takes place. Humor emerges when an incongruity is resolved: the punch line, in some particular way, becomes in line with the information received earlier in the set-up part of the joke. Suppose that the prediction of the outcome of the story or cartoon is not compatible with what we expected (incongruity detection: one stage of two-stage model), we have to figure out the rule to make the ending follow the preceding material. If we can find the rule, we solve the problem (incongruity resolution: the other stage of the model). As a result, humor appreciation is the process of detecting problems and solving problems. As the dominant model illustrating incongruity theory, the naming of this model is a two-stage model, but the model also stresses the after effect of incongruity resolution, laughter (see the bottom items of Fig. 6). Laughter is an indispensable stage of humor appreciation, which reflects the affective component embedded inside humor and shows a complete humor definition as well.

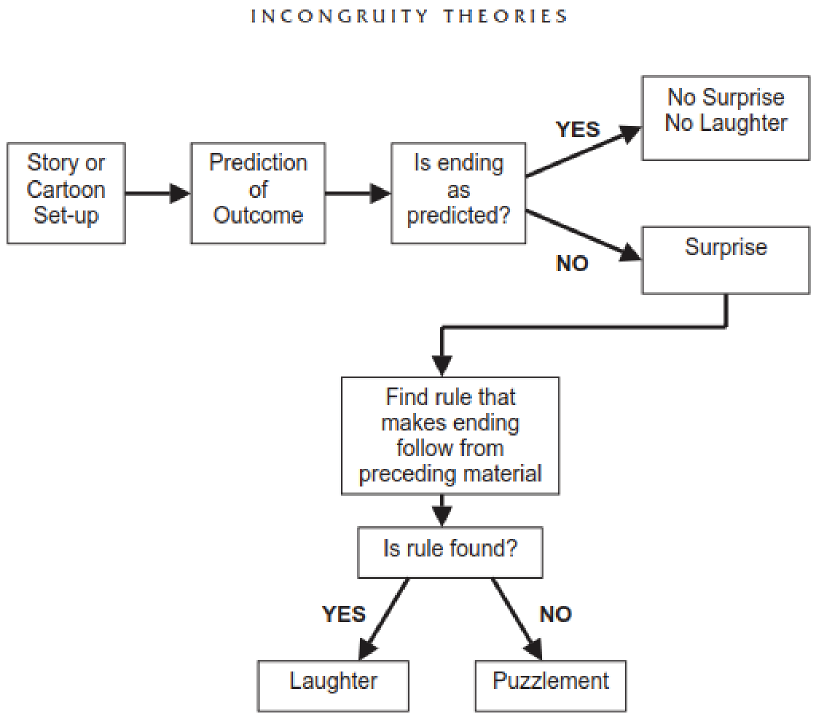


Figure 6 Incongruity Detection-Resolution Model (Suls, 1972; Martin, 2010)

Though the model mainly consists of two stages, it can be further decomposed into more substages. Due to the development of brain imaging techniques, researchers indicated more evidence on incongruity-resolution model of humor appreciation by ERPs (event-related potentials). For example, Goel and Dolan (2001) conducted experiments on the separation of two stages in humor appreciation: humor cognition and mirth. Then researchers supplemented the model by refining it to three-stage model: incongruity detection, resolution and appreciation (Feng Y et al., 2014), and four-stage model: inconsistency detection, evaluation, resolution and appreciation (Tu et al., 2014). In brief, incongruity theories focus on the cognitive elements of humor, with the two conflicting things forming the basic structure and the resolution forming the key to mirth.

4.2.1.2 Semantic-Script Theory of Humor (SSTH) and General Theory of Verbal Humor (GTVH)

SSTH, built on the Incongruity Theory, was introduced by Victor Raskin in "Semantic Mechanisms of Humor", which was published in 1985. Since its publication, the concentration of linguistic humor research has been strongly cognitive, as SSTH and its further developed theory "GTVH" are deeply rooted in the foundations of Cognitive Linguistics (Attardo, 2017).

Raskin's SSTH was the first cognitive-linguistic-based theory of humor, which mainly studied humor in terms of jokes. The theory defined "two conflicting things" in other theories as "two conflicting scripts" to give prominence to viewing the humor from the perspective of linguistics. Specifically, the scripts represent the common sense the cognitive structures stored in the mind of the native speakers (Raskin, 1979). "The punchline of a joke triggers the switch from one script to the other by making the hearer backtrack and realize that a different interpretation of the joke was possible from the very beginning (Attardo and Raskin, 1991)," revealing that the core of SSTH is the resolution of two conflicting scripts. However, this theory only accounts for verbal humor, jokes in particular, not covering all humor types.

GTVH, with its advantages over SSTH to cover all humorous texts by the inclusion of Narrative Strategy put forward by Victor Raskin and Salvator Attardo based on Raskin's ideas of Script Opposition, highlights six levels of independent Knowledge Resources (Hofstadter and Gabora, 2013). They are

1. SO: the Script Opposition of the SSTH;
2. Logical Mechanism (LM): corresponding to the resolution phase of the incongruity / resolution models;
3. Situation (SI): referring to the 'props' of the joke, the textual materials evoked by the scripts of the joke that are not funny;
4. Target (TA): what is known as the butt of the joke;
5. Narrative Strategy (NS): the 'genre' of the joke, such as riddle, 1–2-3 structure, question and answer, etc.;
6. Language (LA): the actual lexical, syntactic, phonological choices at the linguistic level that instantiate all the other choices.

Willibald Ruch, well-known in the research of humor, partially succeeded in replicating the ordering of the Knowledge Resources (Krikmann, 2006). Nevertheless, the Knowledge Resources has been evidenced to be a valuable research field, but needing more investigations (Graban T.S., 2008).

4.2.2 Functional theories of humor

4.2.1.3 Superiority Theory

The Superiority Theory was the only dominant and developed humor theory during a particular period of time in history, lasting for about 2000 years, with its essence to convey the feelings of superiority over others (Morreall, 1983), which can be traced back to Plato and Aristotle, who proposed very valued insights into other broader issues. Following Plato, Aristotle put forward that laughter occurred mainly in response to weaknesses and ugliness due to the comparisons with others, which signified that the Superiority Theory was deeply rooted in the social state of ancient Athens, with the social hierarchies being very strict. Labeled as anti-society by a great number of scholars in history, this theory is not so popular nowadays like hundreds of years ago.

In the 17th century, Thomas Hobbes continued with Plato's thoughts, being critical about using laughter as the tool to despise other people's weaknesses, though stemming from individualistic and competitive nature of human being (Raskin, 2012). "The passion of laughter is nothing else but some sudden glories arising from some sudden conceptions of some eminence in ourselves, by comparison with the infirmity of others or with our own formerly (Thomas Hobbes, 1651)." This point of view was differentiated from that of Plato and Aristotle according to "who is thought to laugh at whom," and the philosophers in ancient Greek discussed it was the authoritative and perfect people who mocked at the vulgar and flawed people, but Hobbes believed that it was the imperfect who laughed at the people having more weaknesses to improve their own self-confidence (Zillmann, 1983). Hobbs can fairly be called the first theorist who presented his views on laughter as part of systematic account of human motives (Billig, 2005).

The roots of laughter in triumph over other people supplied the basic ideas for superiority theories. The principle of superiority, emphasizing that laughter at the shortness of others, was essential to the humor experience, reflected the negative way to interpret humor, contrary to the general idea that humor bore positive nature, which seemed so out of tune with ideological positivism, implicating the connotations of power-protection, hierarchy and ideological self-delusion (Billig, 2005).

Charles Gruner (1978), a contemporary advocate of superiority theories, viewed humor as playful aggression rather than real aggression and argued that the driving force for survival was the competitiveness and aggressiveness underlying human-being evolution, which depicted a more positive perspective on the Superiority Theory underlining self-esteem and feelings of competence. "Humor, while not intrinsically connected with hostility, aggression or transgression, often overlaps with some negative thoughts: people often joke about what they dislike or feel superior to, and the dislike or superiority adds to the liking of humor (Raskin, 2008)." Although the supporters of the superiority theories indicated that all types of humor can be explained under the frame of the Superiority Theory, some researchers concluded that it would better be suited for a particular kind of humor, for example, aggressive humor (Lefcourt and Martin, 1986).

4.2.1.4 Relief Theory

In about 1800s, the Relief Theory was developed in the same time with the Incongruity Theory, weakening the dominant position of the Superiority Theory. The Relief Theory put its stress on the physical responses to humor, with the nervous system being the center in discussion, not mentioned in the Superiority Theory and the Incongruity Theory (Morreall, 2011). Shaftesbury, in early 18^{th} century, for the first time, gave a vivid illustration for the Relief Theory against the contemporary physiology knowledge background. He stated, "the natural free spirits of ingenious men, if imprisoned or controlled, will find out other ways to motion to relieve themselves in their constraints; and whether it be in burlesque, mimicry or buffoonery, they will be glad at any rate to vent themselves and be revenged upon their constrainers (Shaftesbury, 1711)." This illustration revealed that, in the Relief Theory, the essence of humor mainly involved a process of releasing stressed nervous energy in the form of free spirits in response to the constraints.

In the next two centuries, Spencer and Freud made some revisions on the Relief Theory, based on the nervous-energy-release function of humor. Spencer argued that emotions were presented in the mode of the nervous energy, driving the movement of muscles, and laughter was the pass way to release the nervous energy to discharge arrested feelings in the absence of other adequate channels (Spencer, 1963). His essay, "On the Physiology of Laughter", stressed that the muscular movements in laughter are not the early stages of larger practical actions such as attacking or freeing; unlike emotions, laughter does not involve the motivation to do anything; the movements of laughter have no object: they are merely a release of nervous energy. In addition, Spencer associated the energy release argument with the incongruity and explained that laughter resulted from the unconscious transfer from great things to small (Kuipers, 2008).

Whereas, in Freudian point of view, laughter was to regulate psychic energy. In the essay, "Jokes and their Relation to the Unconscious", Freud (1960a) argued that "three laughter situations (joke, comic and humor, concerning certain psychological tasks) had their own specific functions to release the nervous energy, and specifically speaking, joke was to release the energy of restricting feelings; comic was to release the energy of pondering; and humor was to release the energy of emotions (Freud, 1960a)." When reading the beginnings of a joke or a story, the body amassed energy, perhaps in the form of anticipation of a punch line or surprise from an unexpected witticism, and in order to return to a balanced state, people had to laugh to expel this stored energy (Salamone, 2017). Simply put, the central argument of the Relief Theory was that human body constantly sought equilibrium, using physiological processes to release accumulated emotional and mental energy.

4.3 Different humor styles

4.3.1 Four styles of humor

Every individual experiences humor in daily life, but the humor styles we employ have distinctive individual differences, being consistent across time while varying slightly depending on the situations (Ruch, 1998a). Different humor styles have specific effects on outcomes. The style of being benign and tolerant to the self and non-injurious to others is broadly defined as self-enhancing humor, and the style of being detrimental to the relationship with others is regarded as aggressive humor; besides, the style of enhancing one's relationships with others in a benevolent way is believed to be the affiliative humor, and the style of being at the cost of the self is self-defeating humor (Martin, 2003). Different styles of humor are conceptualized based on different functions of humor, either the functions on the self: like self-enhancing style and self-defeating style, or the functions on others involved in the humorous activity: like aggressive style and affiliative style. Moreover, from the perspective of the attributes of humor style, two of them are basically benign, like self-enhancing style and affiliative style, and two of them are relatively detrimental, either to the self or to others, like aggressive style and self-defeating style. These four humor styles are correlated with personality characteristics to some degree.

Affiliative humor: people tell or participate in the conversations about some funny experiences or jokes to set up or consolidate the relationship with others in a way of both being accepted by others and accepting others. This style of humor usually has great connections with the personalities of being extraverted, bright, close to friends, satisfied with relationships and positive in emotions (Martin, 2003). The affiliative humor style also serves as a mediator between the attachment style of anxiety and relationship satisfaction (Cann et al., 2008).

Self-enhancing humor: people who employ this style of humor have the inner intention to avoid negative emotions and keep a positive outlook in the way of life, which is related to the coping mechanism. This style of humor is believed to be negatively related to negative emotions such as depression and anxiety and, more generally, to neuroticism, and positively related to openness to experience, self-esteem and psychological well-being (Martin, 2003).

Aggressive humor: it is a kind of disparagement humor, connected with sarcasm, teasing and ridicule (Zillmann, 1983), with potential hurtful effects on others. This style of humor is believed to be positively related with negative emotions and negatively related with positive emotions.

Self-defeating humor is to entertain other people by degrading oneself or to be involved in being degraded by other people, which reflects the emotional neediness, avoidance and low self-esteem to some extent (Fabrizi and Pollio, 1987). It also has positive correlations with negative emotions and negative correlations with positive emotions.

Researchers usually categorize affiliative humor and self-enhancing humor into the positive humor group, and categorize aggressive humor and self-defeating humor into the negative group. Studies indicated that affiliative and self-enhancing humor were interrelated with more self-respects, more abilities to deal with difficulties and positive judgement of self-evaluation, and by contrast, aggressive and self-defeating humor styles were interrelated with less self-respects, greater depression or anxiety and negative judgement of self-evaluations (Kuiper et al., 2004). Similar findings were suggested by other studies. For example, affiliative and self-enhancing humor styles were demonstrated to be positively correlative with optimism and negatively correlative with anxiety and depression, and by comparison, aggressive and self-defeating humor styles were negatively correlative with optimism and positively correlative with psychological distress (Yue et al., 2010). Two positive humor styles were positively connected to happiness, whereas two negative humor styles were negatively connected to happiness (Ford et al, 2014).

4.3.2 Humor Style Scale

Humor Styles Questionnaire (HSQ) was developed by Martin (2003), which is the first self-report-type scale with validity and specificity to analyze the way and the degree in which people use humor. It was designed to research the individual differences in the usage of humor styles and how these differences affect people's lives (Martin et al., 2012). This questionnaire contained 32 items, which mainly measured the correlations between the usage of humor and the enhanced relationships with others, and whether the usage of humor was to set up affiliative relationships or be detrimental to others. The answer type in the questionnaire was to rate the degree of participants' responses to humorous stimuli, including 7 degrees, from totally disagree to totally agree. It was widely used in different relevant studies and it had been further developed into different versions suitable for different people from different countries and in different life phases. It was also adapted to be suitable for younger children (8-11 years old) (HSQ-Y) by three separate studies on the basis of HSQ, including the assessment of aggressive and affiliative humor among children, the adaptation of all four humor styles administered by a measure of friendship quality and peer reports of four humor styles, with the results suggesting that HSQ-Y was found to be a reliable and valid measure of four humor styles in children aged 8-11 years old (James and Fox, 2016).

Comprehensive understandings on the humor styles people employ in daily lives help artifact designers become more sensitive and careful to take both potential users' personalities and their preferred humor styles into the consideration to include more individualized and positive stimuli in the intervention materials.

4.4 Factors influencing humor appreciation

4.4.1 Personality factor

Personality is a set of individual differences with a number of aspects connected to social relationships, values, attitudes etc., unconsciously causing the differences in people's behavior. Generally, personality can be dissected into five factors: openness, conscientiousness, extraversion, agreeableness and neuroticism. In simple terms, we usually divide the personality characteristics into two: one is extraverted type and the other is introverted type. In 1940s, Eysenck (1942) started to conduct factor analysis research in humor appreciation and investigated the correlations between humor-rating and traits of character, indicating that extraverted people were fond of simple and sexual jokes, while introverted people were fond of complex and nonsexual jokes. According to the three components (cognitive component, social component and affective component) involved in humor concept analysis, people with different personalities are indicated to enjoy different elements of humor: introverted people tend to enjoy more about the cognitive element, while extraverted people tend to prefer orectic or affective element (Martin, 2010). Extraverts are somewhat more likely than introverts to enjoy all kinds of jokes and cartoons and people who generally experience more negative emotions such as anxiety, depression or guilt, tend to dislike all kinds of jokes and cartoons (Ruch, 1992).

The degree of extraversion-introversion had significant impacts on both the amount and the style of humor an individual initiated in social interactions (McGhee, 1986). Researchers (Damico and Purkey, 1978) conducted the studies of personality's influence on humor from a sample of 3500 eighth-grade pupils. They concluded that some personalities, such as asserting, unruliness, attention seeking, leadership and cheerfulness, were presented in the class clowns compared with nonclowns, identified by peer nominations. Then Ann Masten (1986), investigating the relationships between social competence and humor appreciation, found that social competence was positively related with humor appreciation and humor generation, like being more attentive, cooperative, responsive, productive, gregarious and happy. People can get the clue of personalities of someone by analyzing the quality and styles of humor they used in daily life, and vice versa, people unconsciously convey their personality features by their usage of humor.

Mobbs et al. (2005) employed brain imaging method to elaborate on the effects of personality on humor appreciation, suggesting that, in a sense, the humor circuitry was mediated by personality, for extraverted people, humor activated the brain regions of right orbital frontal cortex, ventrolateral prefrontal cortex and bilateral temporal cortices, and there were positive correlations between extraversion and the degree of the brain activities caused by humor stimuli; for introverted people, humor solely elicited the brain region of the bilateral amygdala. Therefore, the data analysis supports the notion that the core neurobiological frameworks in humor circuitry are regulated by personality. To examine the correlations between anxiety and the appreciation of specific types of humor, Samson et al. (2012) conducted an experiment by using three types of cartoons and a control condition as the stimuli to rate their comprehensibility and funniness. The data results showed that there was no difference in cognitive process of humor between highly socially anxious people and normal people, but highly socially anxious individuals were affected by the stress from theory of mind humor, which interfered with the ratings on their own amusement.

In short, different factors of personality have specific effects on humor appreciation, demonstrated by both psychological and neural experiments mentioned above, and the employment of specific types of humor is correlated with the particular personality of each individual. To clarify the relationships between personality and the usage of humor is very significant for the use of the future artifacts. To mediate the negative mood of people in need, the design concept of the potential technical artifacts has to firstly consider the traits of personality of the individualized artifact users to accurately intervene in their cognitive processes and emotional responses.

4.4.2 Gender factor

The early humor research indicated that men preferred producing humor, while women preferred appreciating humor instead of producing humor by themselves, but with the findings being questioned due to the gender bias inherent in the research (Martin, 2010). Before the feminist movement, many jokes that men preferred were the ones about disparaging women or about sexual topics, so women certainly were more likely to listen instead of generating this kind of humor. Since the feminist movement in 1970s, the realization of gender equality has been in process, and more studies, including humor studies, have been conducted on gender issues by transferring to the spontaneous creation of humor in naturalistic social contexts to avoid the gender bias.

Gender influences humor, sometimes overtly and sometimes covertly. For the usage of different humor styles, men and women differ overtly. McGhee (1979) proposed that women tend to use more self-disparaging humor than men. Other research (Crewford and Gressley, 1991) indicated men enjoyed hostile jokes and slapstick humor, but women enjoyed telling the humorous stories happening on themselves. In addition, males prefer using aggressive and self-enhancing humor, whereas females have more empathy (Wu, Lin and Chen, 2016); males preferred unfriendly humor styles but females preferred affiliative humor style to improve interpersonal relationships (Chan et al., 2009).

For the goals of using humor, men and women are covertly unlike in some way. Deborah Tannen (1990) indicated that goals of using humor in social communications were distinct between men and women: women used humor to convey friendly and intimate information, but men used humor to show their advantages. Analogically, females mainly employed humor to establish the states of being united or intimate with other people, while males were inclined to use humor as a tool to win over others (Crawford, 2003). Besides, Martin et al. (1993) researched naturalistic laughter in social communication contexts, showing women were significantly more likely than men to report laughing in response to humor arising spontaneously in social situations. Lampert and Ervin-Tripp (1998) also centered on socialization, social status and dispositional attitudes to account for gender differences in humor appreciation: (1) men display a greater use of humor than women; (2) men evidence a greater liking for humor, especially humor with aggressive and sexual themes; (3) both men and women are inclined to make and enjoy jokes directed at women more than jokes directed at men. Moreover, men paid more attention to their partners' acceptance on the humor they produced, while women focused not only on humor production but also on acceptance; women were more likely to like those who generated humor for different relationships, whereas men were more likely to like those who appreciated their particular humor styles for sexual relationships (Bressler et al., 2006).

The influence of different genders on humor appreciation was also demonstrated by brain imaging method. In a child-sibling pairs study, Vrticka et al. (2013a) revealed that increased activities of humor stimuli occurred in bilateral temporo-occipital cortex, midbrain and amygdala in girls, which reflected that sex divergence in reward and expectations had already been presented in childhood.

Gender issue is a topic researchers have to discuss in any design concept due to its profound influences on potential users' biological, psychological and societal states. In the design concept on emotion mediation in particular, gender differences should be paid more attention to avoid the sensitivity stemming from the gender bias, for instance, in selecting the intervention materials.

4.4.3 Aging factor

Aging is a natural and universal phenomenon common to all living things, which is a process that starts when a person is born and progresses throughout one's whole life, having different effects on both physical and psychological conditions and influencing people's cognition and affects. For infants, smiling and laughing are very significant ways of socializing with their caregivers for survival. The normal children's responses to humor obviously represent a complex interplay between affective and cognitive components, and efforts to identify more sharply the contribution of each are required (Prentice and Fathman, 1975). Humor, during adolescence, may be seen to have adaptive and developmental significance (Simons et al., 1986). For older adults, aging is accompanied by the decrease of some cognitive abilities, such as abstract reasoning, thinking flexibility and working memory, which play the key role in understanding humor (Shammi and Stuss, 2003). The ability of humor appreciation develops with the improvement of one's cognitive ability, and the general tendency is to ascend across infancy, childhood, adolescence and younger adulthood, but it will then fall down a little bit during one's late adulthood because of the slight decline of one's cognitive ability (Li et al., 2017). However, a study indicated that, as for people aged above fifty, the increase of the age was correlated with lower abilities in understanding humor but with greater enjoyment (Schaier and Cicirelli, 1976). At the beginning phase in lifespan, children are gradually more capable of understanding more complicated humor with the increase of their abilities in the course of growing up. While when people grow into adults and their cognitive capabilities reach a certain level, they will lose their initial interests in the low-cognitive-level jokes. In the older age, the cognitive abilities decrease progressively so that people's abilities of understanding jokes also go down, giving rise to their more enjoyment in joke appreciation.

Humor styles (such as affiliated humor, self-enhancing humor, aggressive humor and self-defeating humor) that people employed bud in the infancy, the initial phase of life, and mainly evolve with the improvement of humor appreciation ability. During childhood, some humor styles are less used in humor appreciation since they are closely related to social interactions and stress, which appear less in this phase of life. When entering the period of adolescence, people will be able to apply all humor styles to humor production and appreciation and keep them in use until late adulthood, often putting particular emphasis on some particular humor styles in different phases. Therefore, the employment of humor styles will go from nonexistence to existence, from single style to mixed multiple styles and finally a specific humor style will be preferred by an individual (Li et al., 2017). As for elderly people, they do not prefer aggressive humor like young people and they are very vulnerable to the humor about old age (Greengross, 2013). Besides, older people may devote more attention to humor that relates to intelligence because of their widespread fear of senility, so older people appear to use humor as a coping strategy to handle the adversities and pains (Nahemow, 2013).

Humor generation, humor appreciation and humor's impacts on life change in correspondence with the increase or decrease in people's cognitive abilities, closely connected to their specific needs in society, psychological conditions and the difficulties they meet (Martin, 2010). In different life phases, humor exerted similar yet different functions. Although, for a whole lifespan, humor is deemed as a social skill to improve interpersonal relationships, in adults, humor is more like an effective tool to seek their own social groups. While for old people, humor is very helpful to cope with the adversity brought by aging. Targeting at different potential artifact users involved in emotion design concept from different life phases, the factor related to age cannot be neglected, because some specific humor stimuli are not appropriate for all groups of people, which plays a decisive role in the intervention effectiveness.

4.5 Sense of humor

4.5.1 Basic understandings of sense of humor

The "sense of the ridiculous", as an early expression to describe the degree of being sensitive to funny material, was replaced by the "sense of humor" in the mid-nineteenth century. Due to the fact that a great number of facets are involved in humor, it is hard to conceptualize sense of humor. According to Martin (2008), sense of humor covers cognitive ability, aesthetic response, habitual behavior pattern, emotion-related temperament trait, attitude and coping strategy. Various elements embedded in sense of humor result in different methods of measurement, such as the ability to create and understand jokes, the ability of humor appreciation, the tendency to laugh frequently, habitual cheerfulness, positive attitude toward humor and the tendency to maintain a humorous perspective in the face of adversity. It is like a repertory grid, small pieces of the construct of humor going into an individual's cognitive map of sense of humor (Thorson and Powell, 1993). Hence, sense of humor is correlated to different dimensions of human: social behavior, cognitive process and traits of character, and vice versa, those dimensions also impact the formation of sense of humor (Martin, 2010). In a way, sense of humor is a way of life about how to get along with people around and "let a smile be your umbrella" authentically reveals the prominent function of it (Thorson and Powell, 1993).

Since humor appreciation needs perspective-changing in the integration of two inconsistent things, it may signify that people who have stronger sense of humor have more abilities to deal with things from different perspectives to keep themselves far away from the pressure derived from difficult situations, decreasing the extent of being anxious or depressed (O'Connell, 1976). Besides, people with a greater sense of humor had a more objective view on their self-identity, keeping in line with what they want to be (Kuiper and Martin, 1993). Individuals with a greater sense of humor also tend to be more creative in other areas (Martin, 2010). On the whole, sense of humor is believed to be a characterization of healthy personality, closely related with self-awareness, insight and tolerance (Allport, 1961), desired by people in social interactions and, regarded by women in particular, as a most popular personality feature in finding their future spouses (Feingold, 1992).

4.5.2 The measurement of sense of humor

Researchers have sought different kinds of ways to measure sense of humor on account of its multidimension feature, such as funniness ratings, self-report, ability test, attitude test and behavioral observation. The funniness ratings of jokes have been used in a good deal of studies as the early attempts to assess sense of humor (Landis and Ross, 1933). In 1970s, researchers conducted studies of self-report method to further investigating humor-related individual-difference dimensions (Martin, 2010).

Svebak (1974), one of the researchers who firstly conducted sense-of-humor research with the method of 'factor analysis', proposed to break with the tradition of using funniness ratings of joke and initiated Sense of Humor Questionnaire, including three dimensions: cognitive ability, on both intelligence and creativity; attitudes toward humor; and emotional traits. Hehl and Ruch (1985) supplemented and further developed Svebak's dimensions to include more detailed assessment on more specific aspects, such as humor-comprehension abilities, humor-expression manners, humor-production abilities, different-type-of-humor appreciation, the degree to which people actively seek out humorous sources, memory for jokes in lives; and the tendency to use humor as a coping mechanism.

To particularly study sense of humor as a moderator between stressors and mood, Martin and Lefcourt (1983) created a Coping Humor Scale, measuring relative values of humor as an adaptive mechanism. Different from other sense of humor scales, this scale was aimed specifically at assessing the extent to which people employ humor as a method of handling stresses. The statements, rated by the participants in the scale, were like "I often lose my sense of humor when I am having problem.", "I have often found that my problems have been greatly reduced when I tried to find something funny in them.", or "I usually look for something comical to say when I am in tense situations."

Perhaps the most frequently used sense of humor scale is the Situational Humor Response Questionnaire (SHRQ), which is used to investigate the coping functions of humor. SHRQ (Martin and Lefcourt, 1984) described a 21-item scale to evaluate individuals' sense of humor as defined in quantitative terms and its validity studies revealed significant correlations between the SHRQ and a number of criteria, such as observed mirth responses during an interview, peer ratings of subjects' sense of humor, a measure of positive mood, and rated wittiness of impromptu comedy monologues. The results showed its validity in assessing humor in productive as well as quantitative terms and provided considerable evidence that validated the SHRQ for both sexes. SHRQ has been translated into many different languages and a large number of studies have provided evidence on its reliability. In detail, SHRQ requires participants to rate answers on a scale from "I would not be particularly amused" to "I would laugh heartily" for twenty-one items: seven items are about pleasant contexts; eleven items are about unpleasant contexts; and three items are self-rating on one's perceived likelihood to laugh in different contexts (Thorson and Powell, 1993).

Another step forward, Lefcourt and Martin (1986) attempted to seek out ways to measure sense of humor from multidimensions by integrating Situational Humor Response Questionnaire, Coping Humor Scale and Sense of Humor Questionnaire. Similarly, Thorson and Powell (1993) also developed a Multidimensional Sense of Humor Scale (MSHS), identifying six dimensions of humor: "(1) recognition of self as a humorous person; (2) recognition of others' humor; (3) appreciation of humor; (4) laughing; (5) humorous perspective; and (6) coping humor." Besides these multidimensional scales, there are some other sense-of-humor scales aiming at measuring specific dimension in humor. Humor Appreciation Measures mainly use funniness ratings on different humorous materials to relate with different personality traits (Martin, 2003). The State-Trait-Cheerfulness-Inventory (STCI) targeted at associating three humor-related states, such as cheerfulness, seriousness, and bad mood with psychometric characteristics (Ruch et al., 1996), indicating that participants with higher scores on this inventory have the tendency to maintain positive emotions in face of stress and difficulties. By far, to measure sense of humor, the above-listed scales are the ones most frequently used. Although there are some newly created scales centering on different ages, areas or specific personal traits, most of them are built on these models.

The measurement of sense of humor is one of the important indexes to evaluate the efficacy of the intervention strategy embedded in the potential artifact in the design concept proposed in this monograph. The various targeted dimensions involved in the sense of humor scales will help to reveal the specific and objective situations of the potential artifact users, such as their cognitive abilities, attitudes and emotional states.

5 COGNITIVE PROCESSES IN HUMOR

5.1 Humor cognition

Cognitive neuroscience examines how cognitive processes can be explained by the structure and the function of the brain (Buckner et al., 1998), beginning to flourish in the 1980s when cognitive psychologists and neuroscientists started to use brain-imaging techniques to record brain activities while people performed cognitive tasks (Waldrop, 1993). Since then, the analysis of the cognition on behavior and mind has entered a new era: a large amount of scientific evidence achieved from the experiments by employing advanced brain-imaging methods, combining with traditional psychological research methodology, provides us with more opportunities to dig in depth into the relationships between brain and behaviors, assisting us in uncovering the truth of the brain.

The investigations into the correlations between brain damage and the corresponding cognition deficits initiated the cognitive neuroscience research, which came after the Second World War when many people with war-related injuries showed certain specific language disorders (Matlin, 2005), revealing a good deal of anatomical evidence on detailed functions of different brain regions. However, it was difficult to collect the evidence in explaining normal people's cognitive processes in the brain. In recent decades, through measuring certain properties of the blood in the brain by Positron Emission Tomography (PET) scans and functional Magnetic Resonance Imaging (fMRI), researchers can determine the brain areas responsible for certain cognitive tasks in normal people. But both PET scans and fMRI have the weaknesses of low time-resolution so that they cannot precisely match the going-on event with the particular time of the processing in the brain (Matlin, 2005). By comparison, the event-related potentials (ERPs) can record every tiny fluctuation of electrical activity, responding to the stimuli from outer world in real time, by placing electrodes on person's scalp, to capture the electrical signals generated by a large number of neurons located underneath (Phelps, 1999), with relatively high time-resolution, but relatively low space-resolution.

Resorting to different brain-imaging methods, humor cognition is being further and more comprehensively studied by emphasizing on the neural circuitry and pathways involved in humor processing. Researchers utilized anatomical analysis to identify the brain functions related to humor cognition and concluded the key role that the right frontal lobe plays during incongruity detection and resolution. The affective component of humor cognition was also examined to be greatly related with the reward system in the brain. Furthermore, through the probe into the cognitive process of humor among normal people, a number of studies verified the significant impacts of humor on social communications, efficient arousal on emotion and great influences on people's health. Relevant influential factors on humor appreciation, such as age, gender, personalities, handedness, etc., were also discussed and tested by brain-imaging methods. Additionally, the analysis of different stages of humor appreciation was demonstrated with ERPs by elaborating on the specific time windows and the characteristics of brainwaves in incongruity detection, incongruity resolution and the emotional response. Beyond that, different neural mechanisms of different types of humor stimuli, such as verbal humor and nonverbal humor, were also investigated in many studies. In general, the interplay between humor cognition and its relevant influences on people evolves over life phases including infancy, childhood, adolescence, adulthood and the old age, decided by individuals' cognitive abilities, personality traits and social contexts.

5.2 Cognitive process in humor in damaged brain

5.2.1 Damage in the right hemisphere

The brain consists of two hemispheres and each hemisphere is responsible for different specific functions in brain. In view of the fact that the right hemisphere is most relevant to the functions of attention, memory, problem-solving, reasoning, social communication, orientation, etc., the damage of it may affect the high-level cognitive processes, including the cognitive process in humor appreciation.

The correlations between the humor processing and the right hemisphere functions mainly began from 1970s, when Gardner et al. (1975) conducted a series of studies making comparisons between right- and left- hemisphere-damaged patients by the method of rating the funniest cartoons. The results suggested that all brain-damaged-patients had great difficulties in detecting humorous cartoons and the performances in left or right hemisphere lesions showed no differences. However, lesions in left or right hemisphere were differentially related with the affective responses in humor processing: the patients who had right hemisphere lesion either showed much more laughter more frequently or no laughter at all. The study drew the conclusion that right hemisphere may be especially significant in processing the emotional responses in humor appreciation.

To highlight the role of the right hemisphere in the cognitive process in humor, a series of comparative experiments between normal people and right-hemisphere-damaged patients were conducted by researchers (Wapner, 1981), and the findings revealed that it was hard for right-hemisphere-damaged patients either in explaining the humorous meanings of cartoons or selecting the correct funniest captions, which signified the critical role the right hemisphere played in humor comprehension. The underlying reasons can be connected with what McGhee (1983) suggested: patients with right-hemisphere-lesions showed deficits in numerous capacities, such as getting connotative meanings of expression, integrating information into coherence, understanding metaphors, detecting incongruous information etc., which also interfered with humor processing.

With the refining of the experimental method, some studies investigated the consequences of deficits in the right hemisphere on the cognitive processes of different humorous stimuli. The verbal material was used to examine the sensitivity to humor in the right-hemisphere-damaged people and the results indicated that they had the ability to recognize the form of the joke. Though they attempted to choose the surprise endings in the experiment, what they chosen was not coherent with the body of the joke, implying that right-hemisphere-damaged people had difficulties in integrating the surprise elements into coherence in humor appreciation (Brownell, 1983). Afterwards, Brownell and his colleagues (1984) further investigated the sensitivity of right-hemisphere-damaged people on their lexical denotation and connotation, critical factors in humor processing, and revealed that they had sensitivity to denotation, but they had a selective insensitivity to connotative facets of meanings compared with normal people, who had flexible sensitivity to both denotive and conative meanings. Then, Brownell (1986) carried on the research on the inference deficits in right-hemisphere-damaged people, showing that they had difficulties in answering inference questions, revising previously acquired knowledge in light of new information and crucial ability in resolving the incongruities in humor processing. Brownell's studies laid a solid foundation for later research on the relationships between the functions of right hemisphere and humor appreciation.

Bihrle (1986) investigated the relationships between hemisphere-damaged aphasic patients and humor processing by using humorous and non-humorous nonverbal cartoons as experimental stimuli. The qualitative error comparison produced in right-hemisphere-damaged patients and left-hemisphere-damaged patients indicated that the damage in different hemispheres impaired different elements of humor processing abilities, with right-hemisphere-damaged patients keeping the sensitivity to the surprise element, but greatly decreased abilities to form the coherence, further confirming the close correlations between the right hemisphere damage and humor comprehension deficits.

After reviewing the relations between humor processing and right hemisphere damage, Shammi (2000) indicated that the right-hemisphere-damaged people had difficulties in humor processing mainly due to their problems in dealing with the incongruous information, for they cannot integrate the detailed information into coherence. In addition, right-hemisphere-damaged people also had impairments in the production of humor, connected to the deficits in language, personality and affective responses. These inferences keep accordance with another relevant study (Blake, 2003), which showed that the reduced ability caused by the right-hemisphere-damage occurred in both comprehension and expression of emotional language, greatly affecting the incongruity integration and affective response in humor appreciation. This study also implied that several concurrent disorders, for example, depression, may exacerbate problems in processing affective languages and humor.

5.2.2 Damage in the frontal lobe

In the early 1890s, researchers (Jastrowitz, 1888; Welt, 1888; and Oppenheim, 1890) described the abnormalities in patients with frontal lobe damage, such as oddly cheerful agitation, the tendency to make bad jokes and peculiar addiction to trivial joking of a sarcastic or hostile nature. Subsequently, in the early part of the century, a number of behavioral deficits had been proved to be rooted in prefrontal damage, under the term "frontal lobe syndrome", which contained a diverse set of deficits in different aspects of people, such as personality, affective and cognitive changes and an impaired sense of humor (Shammi, 2000).

A large number of clinical reports listed similar symptoms: humor and laughter are highly exaggerated and are expressed at inappropriate time and places, which is often seen as a result of frontal lobe lesions related with personality and emotional changes (Shammi, 2000). Humor appreciation was examined to be specifically correlated with many functions mediated by the frontal lobe, including problem-solving, working memory, cognitive flexibility, abstraction and directed visual attention (Shammi, 2000). Impairments in these functions result in the corresponding impairments in humor appreciation, which provides a compelling argument in support of viewing humor as a frontal function.

In detail, the role of the frontal lobe in behavior can be represented by four basic operations (Alexander et al., 1989) (see Fig. 7). The first operation, like memory, motor and alertness in posterior/basal areas, are subordinate to a second operation, drive, the ability to initiate, modulate or inhibit cerebral activities in prefrontal area; cognition, visual-spatial and emotion in the posterior/basal area are also subordinate to another second operation, sequencing, the ability to maintain information in meaningful interrelations.

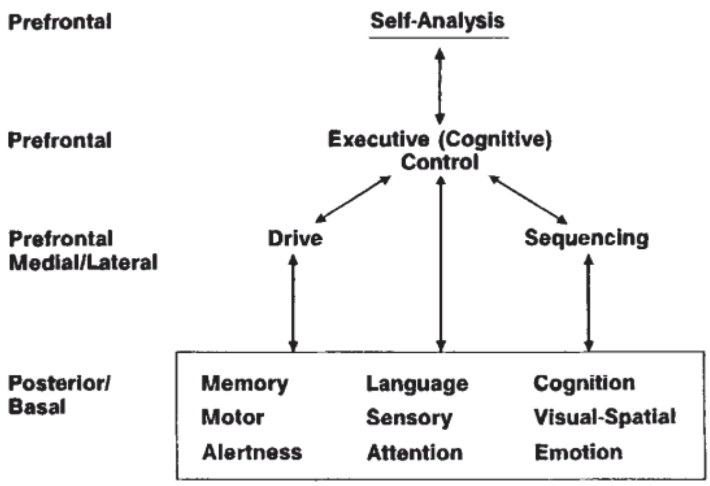


Figure 7 Schematic overview of the influence of the functions in the prefrontal lobes on other mental functions (Alexander, Benson and Stuss, 1989).

Both drive and sequencing are subordinate to the third operation: executive/ cognitive control. Compared to memory, motor, alertness, cognition, visual-spatial and emotion, language, sensory and attention are directly subordinate to the third operation of executive/cognitive control, which is subordinate to the fourth operation, self-analysis, the ability to reflect on the information and the processes of cognition. Considering that the cognitive process in humor appreciation involves many elements presented in the first operation in frontal lobe functions model, such as memory, language, attention, cognition and emotion, the damage in frontal lobe may, to a great extent, hinder humor appreciation.

Combining with the above-mentioned close correlations between right-hemisphere-damage and the difficulties in humor appreciation, we may deduce that the frontal lobe in the right hemisphere plays a decisive part in humor processing. Similar conclusions were also reached by other researchers (Shammi and Stuss, 1999), which indicated that the individuals with the damage in the right frontal lobe reacted less to humorous stimuli, with diminished physical or emotional responses, due to their malfunctions of right frontal lobe in information coherence.

5.3 Neural correlates of cognitive process in humor appreciation

5.3.1 From the perspective of different dimensions

5.3.1.1 Space dimension

Neuroimaging has helped define the big picture of human brain functions at the system level, and its macro view of functional regions activated in a given cognitive process complemented the micro view offered by invasive cell recording (Kriegeskorte, 2007). Though fMRI is a powerful tool for localizing a certain cognitive task in a particular point among tens of thousands of distinct neuroanatomical locations in a few seconds, the Blood-Oxygenation-Level-Dependent (BOLD) response analyzed by fMRI is too slow to further display the temporal dynamics (Debener, 2006). Thus, fMRI usually provides the advantages in analyzing the regions of brain activities of different cognitive tasks because of its high spatial resolution, achieving many reliable and valuable findings in the research of cognitive process in humor appreciation. However, numerous relevant studies are scattered in different facets of humor processing, without systematicness.

In this monograph, to present the systematic features of fMRI humor research, the humor-related fMRI studies were sorted out and classified into groups according to different specific research goals.

To investigate different stages of humor processing

Generally speaking, humor processing includes two stages: cognitive stage and affective stage (Gardner et al., 1975), referring to the stage of the incongruity detection and the incongruity resolution, and the mirth or the emotional responses to the resolution of the incongruity. To segregate the cognitive stage and the affective stage in humor processing, researchers (Goel and Dolan, 2001) experimented with event-related fMRI by employing semantic and phonological jokes as the stimuli and currently, it is one of dominant reference papers in this field. The findings provided the stage-analysis evidence on humor processing: cognitive stage and affective stage of humor appreciation have differential systems, with semantic jokes and phonological jokes activating different neural networks (see Fig. 8). In detail, the semantic jokes involved the activation in bilateral temporal lobe networks, while the phonological jokes involved the activation in left hemisphere networks focusing on the speech production regions. In joke appreciation, medial ventral prefrontal cortex was activated and covaried with subjective funniness ratings, which suggested that the affective appreciation of humor involved access to the central reward system.

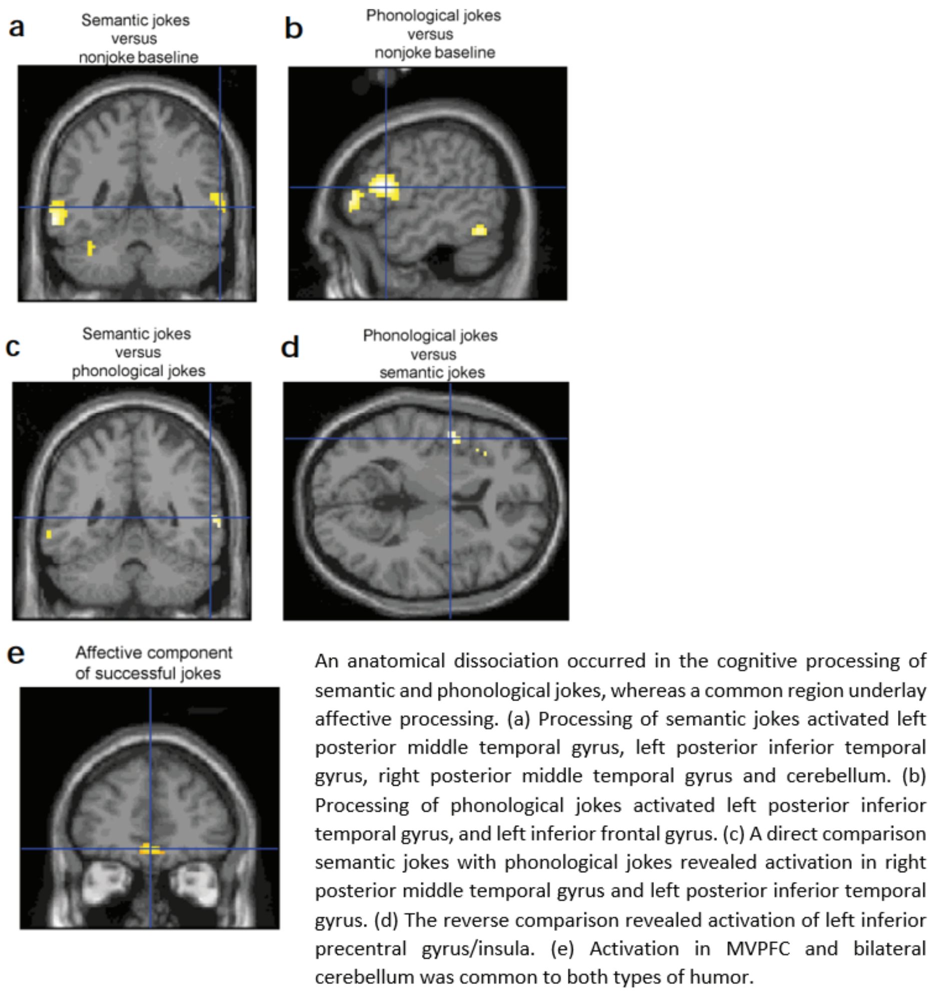
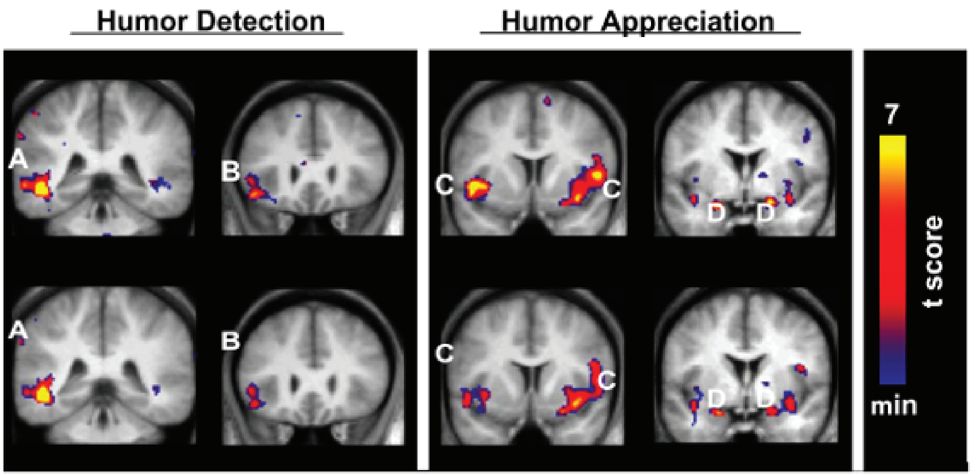


Figure 8 An anatomical dissociation of cognitive component and affective component in semantic jokes and phonological jokes (Goel and Dolan, 2001).

Moran et al. (2004) also conducted an fMRI experiment to segregate different stages in humor processing by dissociating humor detection from humor appreciation (referring to the affective component or mirth in humor processing in this study) with dynamic and real-life material as the stimuli, which were popular episodes of TV sitcoms “Seinfeld” or “The Simpsons”. The data results were discussed in the context of combining the knowledge of humor processing with the knowledge of language processing to elaborate on the fact that humor processing actually involved two facets: the language understanding and the emotional response, which can also be extended to other types of humor. Brain regions dedicated to resolving contextual ambiguities are likewise engaged during humor detection, and similarly, the mirth depends on brain regions necessary for emotional sensation, and the findings revealed that humor detection elicited the increased activities in left inferior frontal and posterior temporal cortices, while humor appreciation (mirth) elicited the increased activities in bilateral regions of insular cortex and the amygdala (Moran et al., 2004) (see Fig. 9).

Different humor stimuli activated different brain regions in humor processing. Two studies mentioned above respectively examined the processing mechanisms of verbal jokes and dynamic humorous material. Then, are there any distinctions between verbal jokes and nonverbal jokes in processing mechanism from the perspective of space dimension? For example, cartoon, very popular and typical humorous stimuli preventing the effects created by the use of language, is different from verbal jokes? In order to dissociate different stages of cartoon processing, Bartolo (2006) conducted a study with fMRI by disassembling the stages of humor detection, incongruity resolution and humor appreciation (affective component), and the findings indicated that inferior frontal and middle temporal gyrus of the left hemisphere played a key role in humor detection in cartoon; both hemispheres (right inferior frontal gyrus, left superior temporal gyrus, left middle temporal gyrus and left cerebellum) were activated during the process of the incongruity resolution. The amygdala was decisive in the humor appreciation or affective component in humor processing.



Whole brain statistical activation maps reveal a functional dissociation between humor detection and humor appreciations. Humor detection led to greater activation in the left posterior middle temporal gyrus and the let inferior frontal gyrus. By contrast, humor appreciation yielded greater activation bilaterally in insular cortex and the amygdala.

Figure 9 The dissociation between humor detection and humor appreciation (Moran et al., 2004).

Samson et al. (2008) utilized more complicated stimulus conditions to investigate the differences in processing mechanisms of different logical mechanisms and further confirm the separation of different stages in nonverbal humor processing by fMRI. The stimuli contained visual puns (visual resemblance), semantic cartoons (pure semantic relationships) and theory of mind cartoons (requiring additionally mentalizing abilities). The results indicated that the pure incongruity resolution mainly activated left-sided network, such as temporo-parietal junction, inferior frontal gyrus and ventromedian prefrontal cortex, which were also involved in the activations elicited by semantic cartoons. While visual puns stimulated more neural activities in the extrastriate cortex and theory of mind cartoons stimulated more activities in mentalizing areas. As a result, different logical mechanisms elicited different specific neural networks.

To further segregate different stages in verbal humor, another fMRI study particularly included garden-path sentences as one condition along with two other conditions, funny and nonfunny jokes, as the stimuli, because garden-path sentences required the same incongruity-resolution processing, but without the affective element. Each stimulus consisted of two parts: set up and punch lines. The findings suggested that “bilateral inferior frontal gyri and left superior frontal gyrus were related to humor comprehension, while the cortical region in left ventromedial prefrontal cortex and the subcortical regions in bilateral amygdala and bilateral parahippocampal gyri were connected to the affective element, the feeling of amusement” in verbal humor processing (Chan et al., 2012) (see Fig. 10).

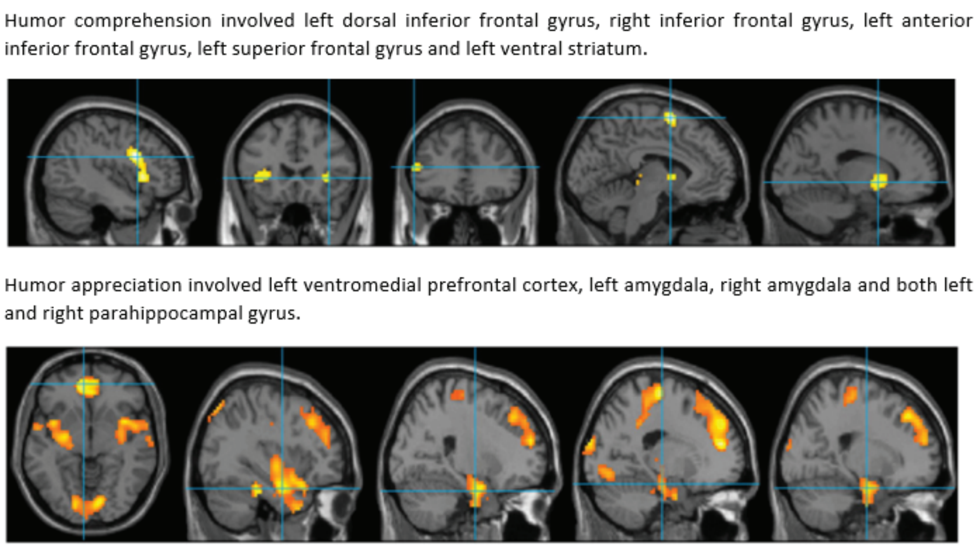


Figure 10 The comparison of brain regions between humor comprehension and humor appreciation (Chan et al., 2012).

After separating the humor comprehension and its affective element in verbal jokes, the same researchers conducted another event-related fMRI study to further isolate the elements underlying humor comprehension: incongruity detection and incongruity resolution (see Fig. 11), incorporating three stimulus conditions: unfunny (with no incongruities) statements, nonsensical (with irresolvable incongruities) sentences and funny (with resolvable incongruities) jokes. The results suggested that the right middle temporal gyrus and right medial frontal gyrus were strongly elicited by the incongruity detection, and the left superior frontal gyrus and left inferior parietal lobule were greatly elicited by the incongruity resolution (see Fig. 12). This study indicated a three-stage neural circuit model of verbal humor processing: incongruity detection and incongruity resolution during humor comprehension, and inducement of the feeling of amusement during humor appreciation or elaboration (Chan et al., 2013) (see Fig. 11).

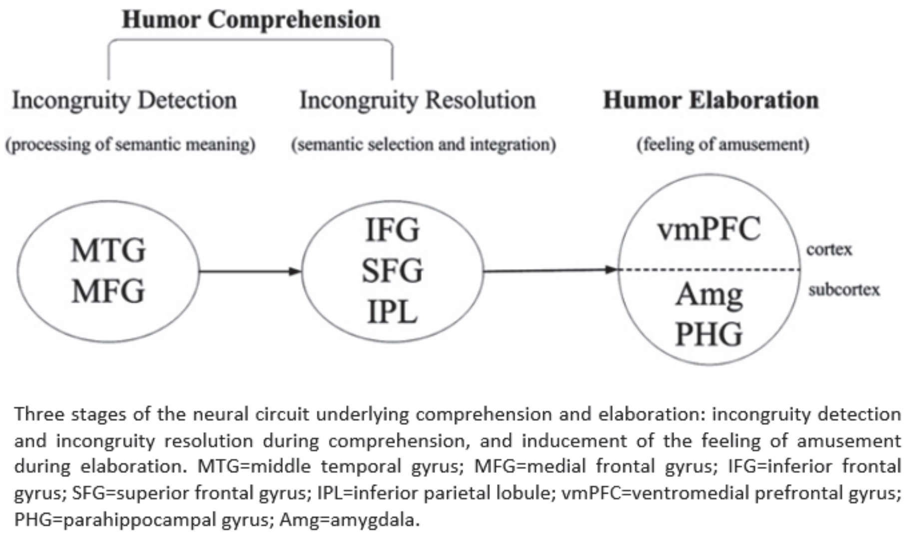


Figure 11 Three stages of neural circuit in cognitive processing in humor (Chan et al., 2013).

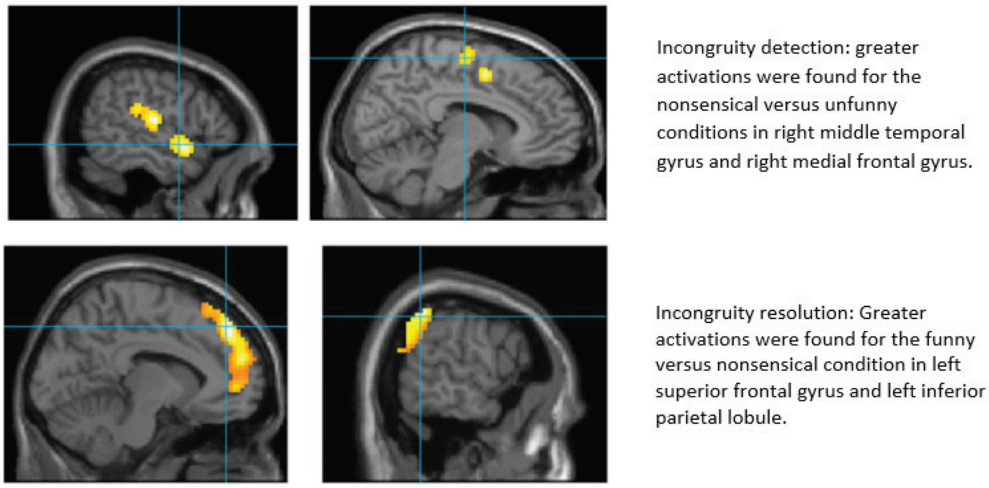


Figure 12 Brain regions activated by incongruity detection and incongruity resolution (Chan et al., 2013).

Another study (Shibata et al., 2014) varied stimulus conditions to continue with the explorations into the verbal humor processing mechanism by using fMRI, and with successfully segregating three stages of humor processing, the findings showed that the punch lines in the funny condition elicited greater activation in language and semantic neural networks, which suggested that the brain regions activated by incongruity detection and resolution overlapped the brain regions activated by language processing to a great degree, similar with Moran's study mentioned previously. The relevant brain regions included inferior frontal gyrus, middle temporal gyrus, superior temporal gyrus, superior frontal gyrus and inferior parietal lobule. In addition, the funny condition also elicited increased activation in the mesolimbic reward regions (Shibata et al., 2014).

To provide more solid evidence in segregating different stages in humor processing, by further manipulating the conditions of stimuli, Campbell et al., (2015) conducted an fMRI study with a trichotomous humor assessment procedure to emphasize individual differences, overcoming previous neglecting specifications on neural correlates. Three types of comics, or three different stimuli, were included in the study: funny joke, non-funny joke (not funny jokes but intended to be funny) and non-joke (not intended to be funny). Non-joke processing signified cognitive processing in normal story-related information expressed in comics without affective component. The comparison between non-funny jokes and non-jokes reflected the neural correlates on humor comprehension, excluding the affective element in humor processing. Funny joke processing signified the cognitive processing in both humor comprehension and humor appreciation (affective element). The contrast between funny jokes and non-funny jokes reflected the affective element, excluding humor comprehension. The findings suggested that the left temporo-parietal junction was mainly involved in humor comprehension and the superior frontal gyrus, besides mesolimbic areas, was primarily activated during the affective phase in humor processing.

In summary, from the perspective of space dimension, the technique of fMRI helps researchers localize specific brain regions in different stages in cognitive process of humor appreciation. Though the specific brain regions activated in humor processing differ due to different types of stimuli (for example, compared with nonverbal humor, verbal humor evidently elicited the language-related brain regions), the general activations in brain regions in the same stage of humor processing are analogical. There is a bilateral activation during the cognitive stage in humor processing, with left hemisphere network, left inferior frontal gyrus in particular, showing stronger activation in humor detection in dynamic material or cartoons (Moran et al., 2004; Bartolo, 2006); with inferior frontal gyrus, superior frontal gyrus and middle temporal gyrus showing stronger activation in incongruity detection and resolution in jokes (Chan et al., 2012; Shibata et al., 2014). As for the affective component in humor appreciation, different experiments with different stimuli concluded similar brain regions: mesolimbic reward regions, with the highlight of amygdala, hippocampus and insular cortex (Moran et al., 2004; Bartolo, 2006; Chan et al., 2012; Shibata et al., 2014; Campbell, 2015).

To investigate the functions of particular brain regions in humor processing

In the previous part, researchers found that different stages in humor processing were closely correlated with the activation in certain brain regions. If inverting the above logics, we may have the question: what is the function of certain brain region in humor processing? To examine the specific functions of particular brain regions in humor processing, researchers conducted a number of fMRI studies. Mobbs et al., (2003) analyzed the functions of mesolimbic dopaminergic reward system in humor appreciation by using funny and nonfunny cartoons as the stimuli and the findings revealed that, compared with nonfunny cartoons, funny cartoons activated in left temporo-occipital junction and interior frontal gyrus extending to temporal pole, and supplementary motor area extending to dorsal anterior cingulate. A subcortical cluster was also observed encompassing the ventral striatum / nucleus accumbens, anterior thalamus, ventral tegmental area, hypothalamus and amygdala. In brief, the experiment presented new findings: nucleus accumbens plays a key role in the mesolimbic dopaminergic reward system and the degree of humor intensity was positively correlated with the BOLD signal intensity in these regions (Mobbs et al., 2003) (see Fig. 13).

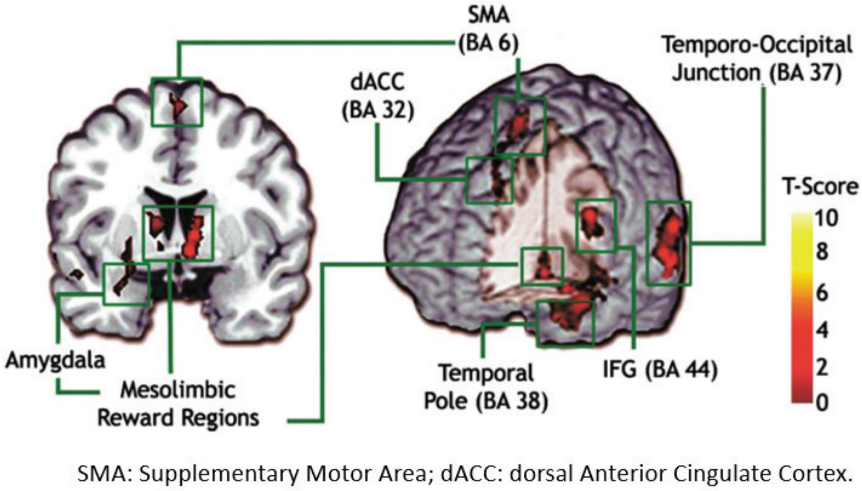
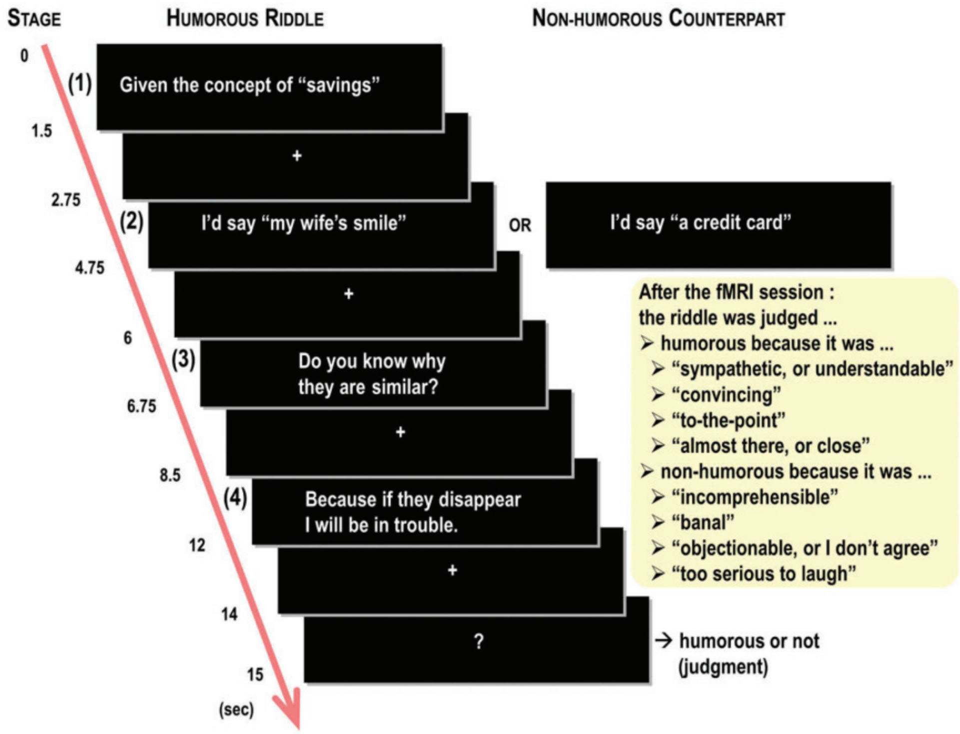


Figure 13 Functional Topographical Map of Funny minus Nonfunny Cartoons (Mobbs et al., 2003).

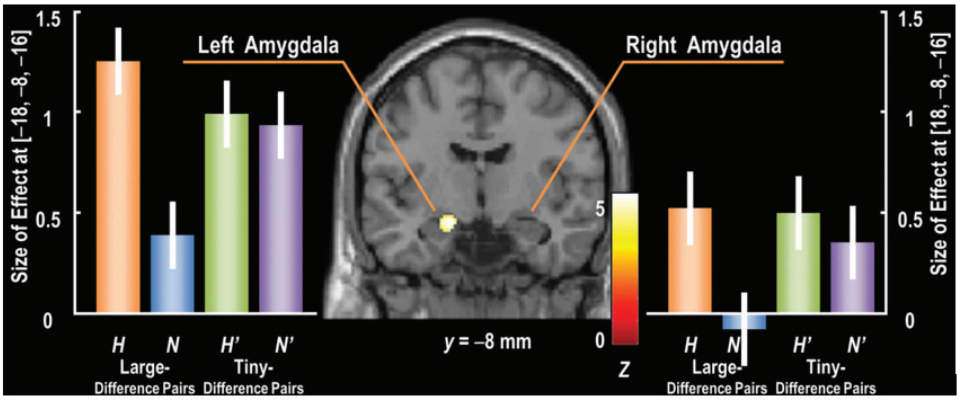
Amygdala is concluded to be a key brain region activated in the affective component in the cognitive process in humor appreciation. Thus, to probe the functions of amygdala in verbal humor appreciation, researchers conducted two experiments by fMRI. In the first experiment (Nakamura et al., 2017), each stimuli consisted of four phases, "Given A (1st phase), I'd say B (2nd phase). Do you know why? (3rd phase) It is because X (4th phase)." The fMRI results indicated that the humorous stimuli activated bilateral amygdala in the 4th phase and the non-humorous stimuli activated left amygdala in the 3rd phase, which suggested that the amygdala has a critical function in the detection of optimal relevance in appreciating humor. In the second experiment (Nakamura et al., 2017), to further examine the role of amygdala in humor appreciation, the experimental design exclusively focused on the resolution phase of incongruity by suspending the humor comprehension process immediately after the perception phase of incongruity. To segregate the neural substrates of incongruity detection and incongruity resolution during humor comprehension, researchers used a humor-producing frame of "Given A, I'd say B, because C" to emphasize on the resolution phase independently by suspending humor processing just after the detection phase (see Fig. 14). The nonsensical sentences activated the right middle temporal gyrus and posterior rostral portion of the medial frontal cortex, representing the detection of the incongruity. In contrast, humorous sentences activated the anterior rostral portion of the medial frontal cortex and the left inferior parietal lobule, suggesting the relevance of these brain areas to the resolution of incongruity. The study also revealed that the incongruity resolution evoked positive emotion, activating the left amygdala (see Fig. 15), which confirmed the role of the amygdala in incongruity resolution in humor appreciation.



In the experiment, the first three stages are used as a context phase and the fourth stage is used as a target phase. In the humorous stimuli, the perception of incongruity arises during the context phase, while the resolution of incongruity occurs at the target phase. On the other hand, in the non-humorous one, no resolution occurs.

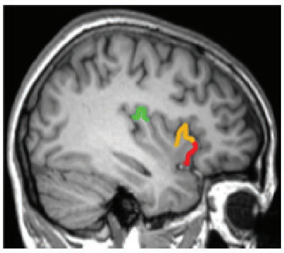
Figure 14 The time course of the experiment with an example (Nakamura et al., 2017).

Though the laughter caused by tickling is different from the laughter caused by humorous stimuli, the analysis of processing mechanism in ticklish laughter can also provide some research background to help understand humor-processing mechanism. To investigate the functions of the insular cortex (see Fig. 16) in laughter, researchers examined regional activation during ticklish laughter, inhibited ticklish laughter, and voluntary laughter. The findings indicated that ticklish laughter was correlated specifically with right ventral anterior insular activity, which was not detected in other two laughter conditions (see Fig. 17). The study drew the conclusion that only laughter that was elicited by emotional stimuli can activate the autonomic arousal in the insular cortex (Wattendorf et al., 2016).



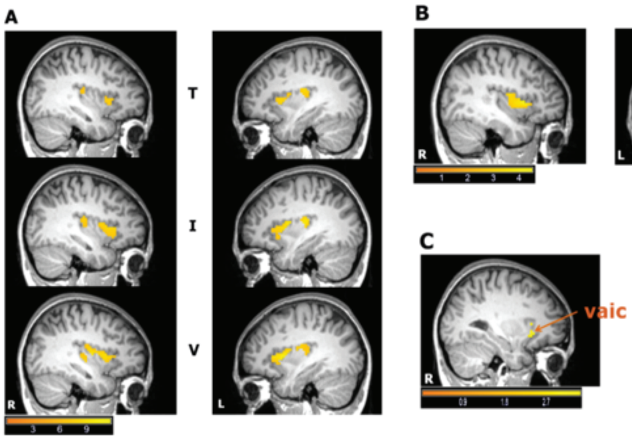
As a main analysis, the experiment conducted the paired t test for the large-difference pairs (H, humorous stimuli; N, non-humorous ones). In the contrast of (H − N), the results found the left amygdala activation (Montréal Neurological Institute [MNI] coordinates [−18 – 8 – 16], family-wise error of $p < 0.05$ as multiple comparisons at the peak level threshold for the entire brain). To show the activation graphs of the large-difference pairs and the tiny-difference pairs (H', stimuli with greater humorousness in the pairs; N', that with less one), a post hoc analysis of 2 (the factor "selection," i.e., large-difference pairs or not) × 2 (the factor "humorousness," i.e., humorous or not) within participant factorial design was used, finding no activation in the tiny-difference pairs (each graph was drawn using the implicit baseline as zero along with the right amygdala [18 – 8 – 16]). Coordinates (y mm) are given in MNI space.

Figure 15 Activation related to incongruity resolution in humor comprehension (Nakamura et al., 2017).



Lateral view on the left insular cortex. The primary interoceptive cortex in the posterior and anterior areas of the dorsal fundus of the insula are marked in green, and the dorsal and ventral portions of the anterior insular cortex are labeled in yellow and red, respectively.

Figure 16 Left insular cortex (Wattendorf et al., 2016).



Insular activity during ticklish laughter, inhibited ticklish laughter and voluntary laughter. A: heightened levels of activity in the insular during ticklish laughter, inhibited ticklish laughter and voluntary laughter. B: the activation elicited by voluntary laughter is greatly stronger than ticklish laughter in the insula. C: the maximum value of activation during ticklish laughter and the corresponding laughter events in the insular cortex. VAIC, ventral anterior insular cortex.

Figure 17 Insular activity during ticklish laughter, inhibited ticklish laughter and voluntary laughter (Wattendorf et al., 2016).

Another study, by using fMRI, examined the differences of cortical regions evoked by humor perception and voluntary 'grinning' at similar nonfunny cartoons. The results indicated that "left temporo-occipitoparietal junction and left prefrontal cortex were activated in humor perception and bilateral basal temporal lobes were activated in humor-associated smiling; bilateral activities in the facial motor regions were elicited by voluntary 'grinning' in the absence of humorous stimuli (Wild et al., 2006)."

On balance, humor researchers paid more attention to three brain areas related with humor appreciation: mesolimbic reward system, amygdala and insular cortex, which are greatly connected to the emotional arousal or affective component of humor processing. However, when exploring into the functions of amygdala, it was found to be closely related with the cognitive component of humor appreciation, including humor detection and incongruity resolution, proposing the importance of amygdala in processing cognitive component in humor appreciation.

To investigate brain regions activated by different types of humorous stimuli

Different cognitive tasks activate different brain regions in the specific neural mechanism. For instances, the visual task activates occipital lobe and auditory task activates temporal lobe. To investigate the relationships between different types of humorous stimuli and their correspondingly activated brain regions, researchers conducted comparative analysis in the neural correlates between incongruity-resolution cartoons and nonsense cartoons by fMRI. Compared with nonsense cartoons, incongruity-resolution cartoons had greater activation in anterior medial prefrontal cortex, bilateral temporo-parietal-junctions, bilateral superior frontal gyri, which suggested more integration of information and coherence building; furthermore, inter-individual differences in experience seeking also had impacts on neural correlates: “experience seeking was positively correlated with humor processing in the left inferior frontal gyrus, middle frontal gyrus and the bilateral temporo-parietal-junctions, which reflected that the experience seekers tried to search novel relevant information (Samson et al., 2009).”

To examine the differences in neural correlates in the serial changes of humor processing, an event-related fMRI study used four-frame manga as the stimuli, with each stimulus including “an introduction (1st frame), development (2nd frame), turn (3rd frame) and conclusion (4th frame, punch line) (Osaka et al., 2014).” Activations in the temporo-parietal-junction were evoked (see ‘Funny: Frame 2 – Frame 1’ in Fig. 18) in the 2nd frame, followed by activations in the temporal and frontal areas during viewing of the 3rd frame (see ‘Funny: Frame3-Frame1’ in Fig. 18); for the 4th frame, strong increased activations were confirmed in the medial prefrontal cortex and cerebellum (see ‘Funny: Frame4 - Frame1’ in Fig. 18), suggesting that humor comprehension evoked activation that initiated in the temporo-parietal-junction and expanded to the medial prefrontal cortex and cerebellum at the convergence level (Osaka et al., 2014).

On the basis of a notion that readers’ mentalizing about words in jokes is essential for perceiving humor, a study was conducted to investigate the difference between point-to-other verbal jokes and point-to-self verbal jokes: point-to-other jokes elicited significant higher activations than point-to-self jokes in right middle temporal gyrus and superior temporal sulcus, reflecting that theory of mind network was more activated when reading point-to-other jokes than point-to-self jokes; what’s more, the whole-brain analysis revealed significant activations in the right middle temporal gyrus and superior temporal sulcus, providing supports for the viewpoint that the right hemisphere, especially the right frontal lobe, was important in theory of mind and humor processing (Feng S et al., 2014).

Researchers also investigated brain activations in response to dynamic joke-show of real-actor by fMRI. The results showed that high-funny-clips elicited more activations in several brain regions involved in reward responses, including the nucleus accumbens, caudate and putamen, indicating that dynamic shows of humorous stimuli involve the activations in reward system (Franklin and Adams, 2011).

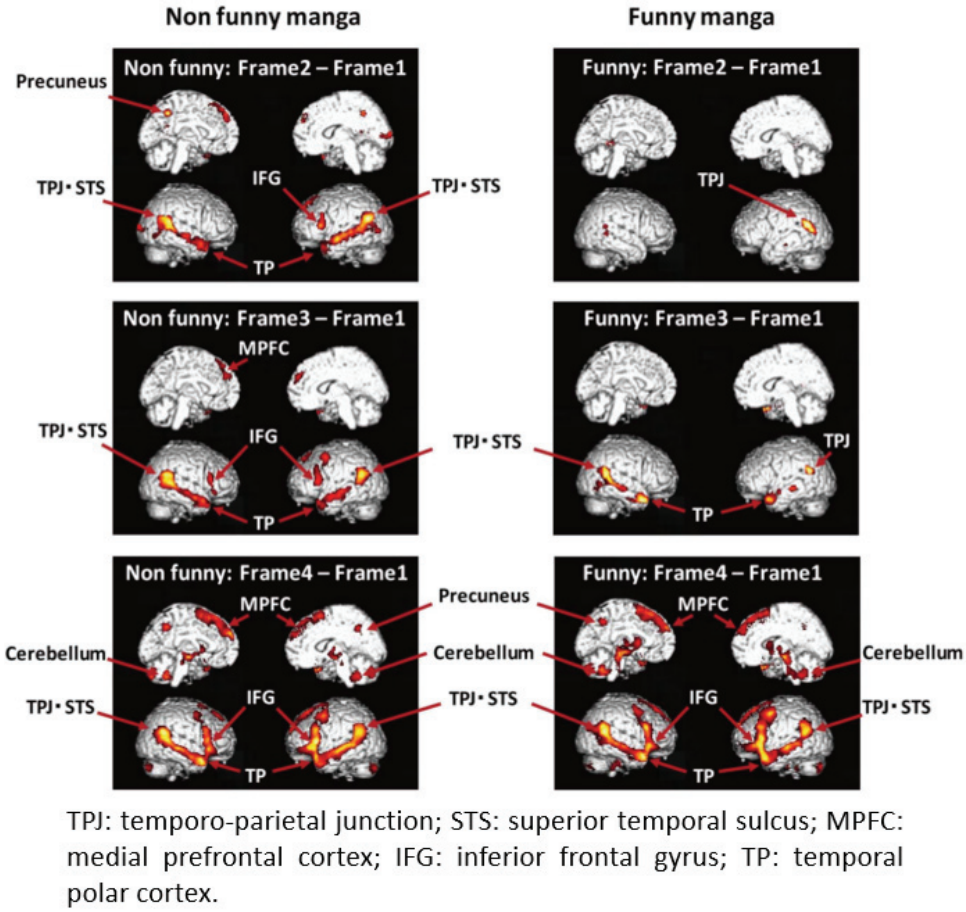


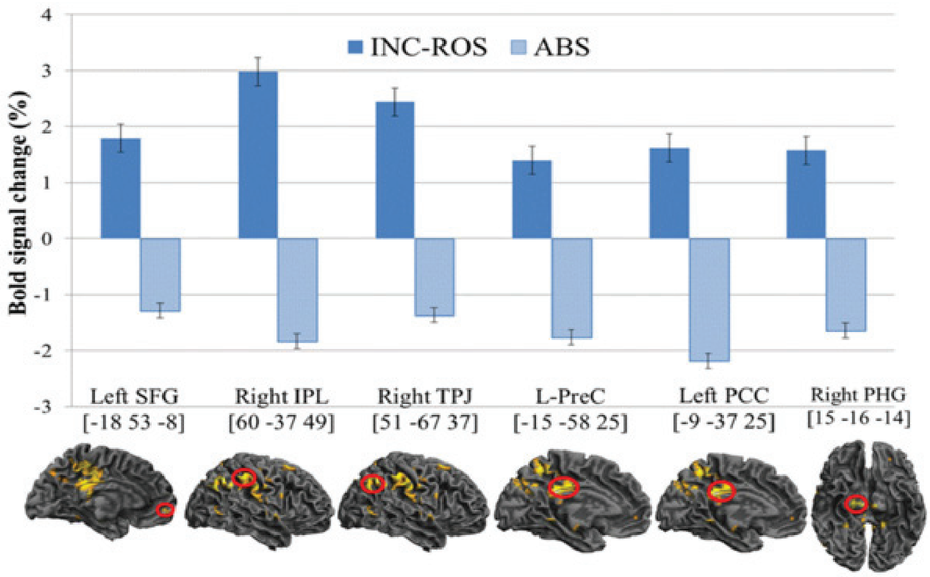
Figure 18 fMRI images of brain areas activated upon viewing the second, third and fourth frames relative to activation upon viewing the first frame (Osaka et al., 2014).

To study neural correlates in the processing of particular joke types, researchers (Chan et al., 2015) employed three different joke types based on different logical mechanisms, including bridging-inference jokes, exaggeration jokes and ambiguity jokes. The findings revealed that the left dorsolateral prefrontal cortex was closely correlated with common cognitive mechanisms and the ventral anterior cingulate cortex was associated with emotion response; the temporo-parietal lobe was greatly related with bridging-inference jokes, suggesting the involvement of theory of mind processing; the fronto-parietal lobe was associated with both exaggeration jokes and ambiguity jokes, suggesting the involvement of executive control processes, such as retrieval from memory, self-awareness and language-based decoding; the emotional response of verbal jokes evoked the activations in the orbitofrontal cortex, amygdala and parahippocampal gyrus (Chan et al., 2015).

To verify whether hostile jokes are funnier than non-hostile jokes, researchers conducted experiments to investigate the differences in their neural correlates. Hostile jokes evoked strong activations in dorsomedial prefrontal cortex and midbrain, reflecting cognitive operations of social motivation, whereas non-hostile jokes evoked strong activations in ventromedial prefrontal cortex, amygdala, midbrain, ventral anterior cingulate cortex and nucleus accumbens, reflecting the social-affective engagement (Chan et al., 2016).

The neural mechanism of absurd (nonsense) humor was examined in an fMRI study (Dai et al., 2017), which proposed a 'dual-path model' in processing incongruity-resolution humor and absurd humor (though containing unresolvable incongruity, still evoking mirth), suggesting that the incongruity detection and resolution in incongruity-resolution humor activated the temporo parietal lobe, relating with perspective taking; the affective response of incongruity-resolution humor activated the posterior cingulate cortex and parahipocampal gyrus, implying event memory retrieval and mirth respectively. In comparison, absurd humor (containing partial resolution) mainly elicited greater activation in the fusiform gyrus (suggesting word processing), inferior frontal gyrus (implying the partial incongruity-resolution) and superior temporal gyrus (reflecting the pragmatic awareness) (Dai et al., 2017) (see Fig. 19).

In brief, due to the complicated nature embedded in humor, any change of the humorous stimuli will elicit its corresponding responses in relevant brain regions, though humor cognitive process has its common mechanism. By fMRI, we can clearly understand that different types of humorous stimuli (such as humorous and nonsense cartoons, four-frame manga, real-life dynamic humor, bridging inference joke, exaggerating joke and ambiguity joke, hostile and nonhostile joke and absurd humor) activate different specific brain regions. However, there are some specific brain regions shared by most types of stimuli: bilateral temporo-parietal-junction, inferior frontal gyrus and amygdala, involved in humor comprehension and mirth.



Incongruity resolution verbal humor demonstrated stronger activation in the left MFG (middle frontal gyrus), left SFG (superior frontal gyrus), right IPL (inferior parietal lob), right TPJ (temporo-parietal junction), left PreC (precuneus), left PCC (posterior cingulate gyrus), and right PHG (parahippocampal gyrus). ROS: incongruity resolution humor; ABS: absurd humor.

Figure 19 Enhanced BOLD signal activation for incongruity resolution contrast absurd verbal humor (Dai et al., 2017).

To investigate the brain connectivity in humor processing

Brain connectivity denotes the anatomical connectivity structure of interrelated aspects between different brain regions, which plays a significant part in determining the functional properties of a neural mechanism. Studies of patterns of functional connectivity (based on coherence or correlation) among cortical regions have demonstrated that functional brain networks exhibit small-world attributes possibly reflecting the underlying structural organization of anatomical connections (Achard et al., 2006). Brain connectivity analysis in humor processing helps to explore functional connectivity between the seed regions and other brain region. The findings showed that left inferior frontal gyrus, the right middle temporal gyrus, the left superior frontal gyrus showed increased connectivity with some relevant brain regions in frontal lobe and temporal lobe, which suggested that the interconnectivity among these regions functioned to integrate the cognitive and affective components of humor to elicit positive emotional responses; the brain regions activated by incongruity detection and resolution overlapped the brain regions activated by language processing to a great degree (Shibata et al., 2014) (see Fig. 20).

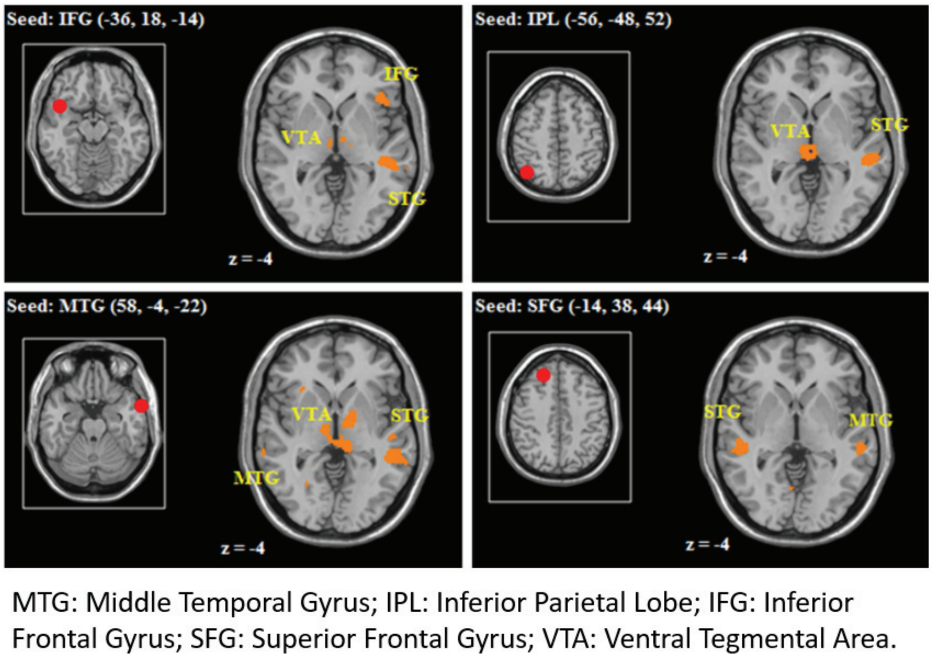


Figure 20 Results of PPI (Psychophysiological Interaction) connectivity analysis. Brain areas showing enhanced connectivity with seed regions (Shibata et al., 2014).

In verifying whether hostile jokes are funnier than non-hostile jokes, the psychophysiological interaction (PPI) analysis demonstrated functional coupling of dorsomedial prefrontal cortex – dorsolateral prefrontal cortex and midbrain – dorsal medial prefrontal cortex for hostile jokes, and functional coupling of ventromedial prefrontal cortex – midbrain and amygdala – midbrain – nucleus accumbens for non-hostile jokes (Chan et al., 2016). The PPI analysis revealed the significance of mesocorticolimbic dopaminergic reward networks for both types of jokes. The more coupling in non-hostile-dependent jokes showed in midbrain-amygdala and amygdala – midbrain – nucleus accumbens, the more affective responses were suggested, indicating that non-hostile jokes were actually funnier than hostile jokes (Chan et al., 2016) (see Fig. 21).

In a nutshell, brain connectivity analysis provides more precise pictures of how neurons and neural networks process information by showing particular correlation patterns of brain regions. According to the above humor-related brain connectivity analysis, frontal area, temporal area and reward systems are the crucial brain regions in cognitive process in humor, which keeps in line with the previous findings mentioned above.

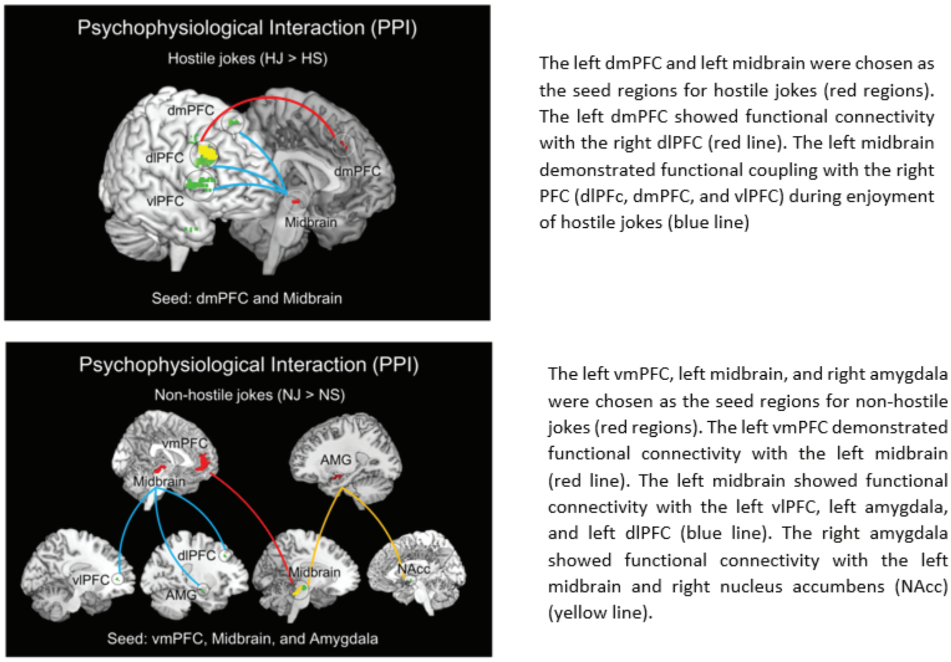


Figure 21 Results of the psychophysiological interaction (PPI) analysis for hostile jokes and non-hostile jokes (Chan et al., 2016).

To investigate brain regions relevant to different personalities in humor processing

Sense of humor is regarded as one of the aspects of personality, suggesting that humor appreciation and personalities embedded in the people who appreciate humor are significantly correlated. In a way, humor and personality intermediates each other. Researchers used MRI to examine the relationships between neural correlates of humor appreciation and personality dimensions, including introversion-extroversion and emotional stability-neuroticism. The right orbital frontal cortex, ventrolateral prefrontal cortex and bilateral temporal cortices concurrently increased with extroversion during the appreciation of humorous cartoons; increases in introversion led to elevated bilateral amygdala nuclei and anterior temporal lobe activation (Mobbs et al., 2005). Emotional stability was correlated with BOLD activity in the mesolimbic reward circuitry including the right ventrolateral prefrontal cortex and orbital frontal cortex, extending to the right caudate and nucleus accumbens. In brief, the data in this experiment indicated that core neurobiological structures in humor circuitry are regulated by personality (Mobbs et al., 2005).

A study (Wu et al., 2016), for the first time, attempted to investigate the neural mechanisms of gelotophobia (an intense fear by being laughed at), revealing that with increasing individual fear of being laughed at, the linking efficiency in superior frontal gyrus, anterior cingulate cortex, parahippocampal gyrus and middle temporal gyrus decreased; however, there were no significant correlations between gelotophilia scores and the topological properties of the brain white matter network.

To investigate brain regions relevant to reviewing effects in humor processing

To compare the differences underlying neural processes between first-time watching and reviewing in humor appreciation, researchers conducted an fMRI experiment in which three comedy clips were shown twice to participants: for the first-time watching, there were significant bilateral activations in frontal pole, right anterior insula, amygdala bilaterally, inferior temporal, cerebella, posterior cingulate and some parietal areas, which were especially important for the incongruity detection-resolution and emotional responses; and for the reviewing, medial and lateral prefrontal areas, frontal pole, posterior inferior temporal areas, posterior parietal areas, posterior cingulate, striatal structures and amygdala showed reduced activity, suggesting the decreased involvement in processing the novelty of the comedic events (Jääskeläinen, 2016).

To investigate brain regions in humor creation

A study, at the first attempt, explored the neural correlates of real-time humor creation by fMRI. The participants in the study constituted three groups: professional comedians, promising amateur comedians and controls (either students or faculty at the university). The stimuli (cartoons) were not funny and the participants were asked to produce either a humorous caption / a mundane caption or no caption to match the cartoon with the purpose of isolating humor generation from humor appreciation. The contrast of humorous caption generation and mundane caption generation revealed the greater activation in bilateral temporo-occipital junction, medial prefrontal cortex and the striatum. mPFC, in particular, helped to direct the search through association space taking place in the temporal regions, and such intervention was needed less for more experienced comedians who, to a greater extent, reaped the fruits of their spontaneous associations (Amir and Biederman, 2016).

5.3.1.2 Time dimension

Different brain imaging methods have different advantages on either space resolution or temporal resolution. EEG (Electroencephalography) signal is directly coupled to neuronal electrical activity and has millisecond precision, and ERPs (Event-related potentials) can be reliably measured by using EEG, a procedure that measures electrical activity of the brain over time using electrodes placed on the scalp (Debener, 2006). ERPs can provide excellent temporal resolution, very suitable to the research questions on the speed of neural activity, presenting the brain features in terms of time dimension targeting at a certain cognitive task. MEG (Magnetoencephalography) employed magnetometers to keep a record of activities of electrical currents. Despite the fact that EEG and MEG signals stem from the same neurophysiological processes, the great distinctions exist, with magnetic fields being less distorted than electric fields by the skull and scalp, resulting in a better spatial resolution of the MEG (Cohen and Cuffin, 1983).

To investigate time windows related to different types of jokes

Du et al. (2013) investigated three-stage model of humor processing - humor detection, resolution and appreciation - with two types of stimuli (funny condition and unfunny condition) by using ERPs. The results (see Fig. 22) suggested that funny items initially elicited more negative ERPs (350-400ms) in the left temporal gyrus and the left medial frontal gyrus, which were involved in detecting the incongruity in humor processing. Between 600-800ms, funny items subsequently elicited more negative ERPs deflections, localized in anterior cingulate cortex, which was involved in the breaking of the expectation. Finally, funny items activated more positive ERPs (1250-1400ms) in the middle frontal gyrus and the fusiform gyrus, related to the affective appreciation stage in joke process.

To further examine the temporal dynamics of humor processing, researchers incorporated three different conditions as stimuli in an ERPs study: jokes, non-jokes and nonsensical sentences. The results indicated that there were strongest negativity in brainwaves between 350-500ms (N400) for nonsensical sentences, which reflected the greatest degree of the incongruity in nonsensical sentences. Jokes and non-jokes elicited more positivity (P600) than nonsensical sentences between 500-700ms, suggesting a more successful reanalysis process during incongruity resolution in jokes and non-jokes than in nonsensical sentences; jokes elicited the most positive slow-wave activity between 800-1500ms, signifying the emotional responses to jokes were greater than the other two kinds of stimuli, revealing three ERP components (N400, P600 and Late Positive Potential) corresponded to three stages of humor processing (incongruity detection, resolution and affective response) (Feng Y et al., 2014).

To explore the correlations between different stages of humor processing and attentional processing, a study employed a dot probe task with three different groups of stimuli: humor versus control, novel versus control and neutral versus neutral image pairs. Exposure durations of 300ms, 400ms and 500ms were selected in order to distinguish between the effects of incongruity detection and resolution. The results indicated that incongruity detection biased attention by 300ms, whereas incongruity resolution may only contribute at 500 ms (Hildebrand and Smith, 2014).

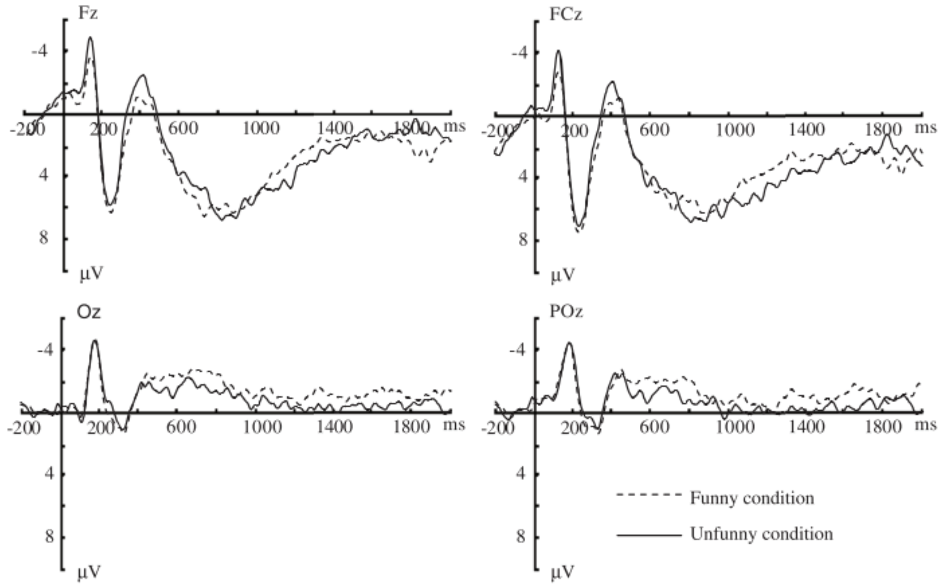
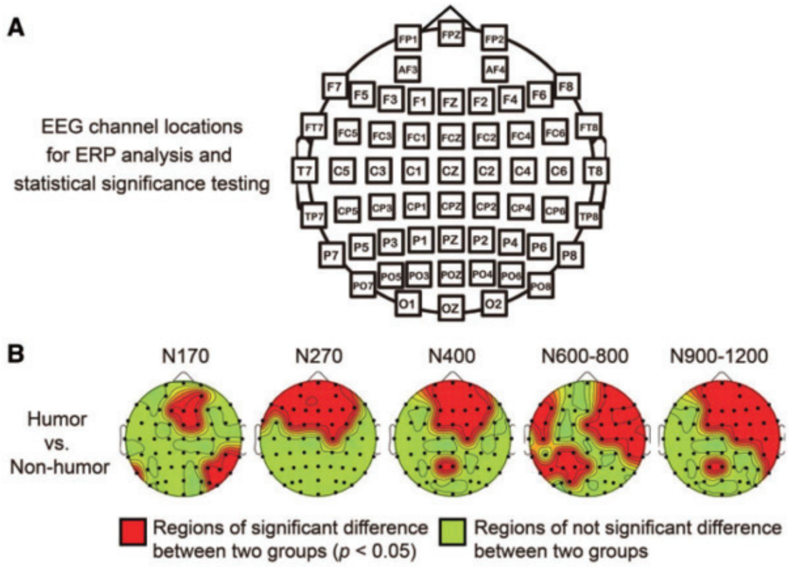


Figure 22 Grand average ERPs at Fz, FCz, Oz, and POz for the funny and unfunny conditions (Du et al., 2013).

To investigate the neuro-cognitive neural substrates of garden-path jokes, a study by using ERPs was conducted with three different conditions (the difference in conditions was achieved by manipulating the endings of the jokes): a coherent ending, a joke ending and a discourse-incoherent ending. The reading-time analysis showed that jokes consumed more reading times than coherent endings; eye tracking analysis found that larger pupil diameters to joke endings reflected greater emotional response; ERP data analysis of all three different conditions reflected the semantic integration difficulties in 400ms; incoherent endings also consumed more reading times, but without emotional response, revealing that garden-path jokes involved a sequential, non-monotonic and incremental discourse comprehension (Mayerhofer and Schacht, 2015).

A study measured the EEG temporal and spectral responses by manipulating the head portraits of celebrities. The findings revealed that the comprehension-elaboration theory in humor appreciation can be illustrated by the measurement of EEG: N170 indicated facial information processing; N270 indicated incongruity detection; N400 indicated incongruity comprehension; N600-800 indicated the late response of incongruity comprehension; and N900-1200 indicated the feelings of humor and amusement produced during the elaboration of humor following incongruity comprehension (see Fig. 23), with significant differences being presented particularly in the right prefrontal and frontal regions (Wang et al., 2017).



The red regions represent electrodes with statistically significant differences; the green regions represent electrodes without statistically significant differences. The results indicated that when comparing between humorous and non-humorous drawings, there were statistically significant differences in the evoked N170, N270, N400, N600-800 or N900-1200 components.

Figure 23 (A) 64 channel locations for ERPs analysis; (B) all ERPs with statistically significant differences in the comparison between humorous and non-humorous drawings (Wang et al., 2017).

A study combined high-density whole-head MEG with anatomical magnetic resonance imaging to further explore the functional anatomy and the temporal sequence of the multi-stage joke-comprehension process by using funny, not funny and nonsensical conditions. The findings revealed that funny punchlines activated the smallest N400 in the stage of lexical-semantic integration in the anterior left temporal area, with the attenuated N400 resulting from the primed 'surface congruity'; then funny punchlines engaged distributed prefrontal areas bilaterally for the incongruity resolution, with the right area searching semantic memory for alternative meanings to comprehend the joke (Marinkovic et al., 2011).

Specifically aiming at investigating incongruity detection and resolution in processing humor, a study employed ERPs and standardized low-resolution brain electromagnetic tomography analysis (sLORETA) to further explore the temporal course and the characteristics in brain activities, with two types of experimental stimuli: funny sentences and unfunny sentences. Findings showed that funny punch lines activated a P2 component followed by a P600 component over centro-parietal electrode sites; the stronger activation of P2 comparing funny with unfunny conditions was located in the superior frontal gyrus and medial prefrontal cortex; the funny punch lines also significantly activated the temporal-parietal regions in P600 component, suggesting that verbal humor comprehension begins with the incongruity detection in the early P2 time window (Shibata et al., 2017), which is different from most previous findings which indicated that incongruity detection started with N400.

In summary, the advantages of ERPs in its high temporal resolution made it possible to segregate humor processing into different stages by identifying prominent ERP components (such as 400ms, 600ms and 800-1500ms). The relevant findings provided more reliable evidence to justify the validity of the Incongruity Theory in a more objective way and contributed further to the in-depth understandings of humor processing, laying a very solid foundation for the applications of humor research into realities.

To investigate time windows related to different factors influencing humor processing

As mentioned before, humor appreciation are influenced by a number of factors of individuals and among those factors, comprehension level plays a decisive role. Coulson and Kutas (2001) investigated the differences between good joke comprehenders and poor joke comprehenders from the ERP effects on the bases of frame-shifting. The findings revealed that both good and poor joke comprehenders showed greater negativity for jokes than nonjokes. The negative activation over anterior left lateral sites for jokes reflected the frame-shifting to reestablish coherence in understanding the incongruities. All jokes activated a left-lateralized sustained negativity for good joke comprehenders, whereas for poor joke comprehenders, they showed only a right frontal negativity in jokes in the time window of 300 – 700ms.

Some genetic factors, such as language lateralization and handedness, affect people's functional hemisphere asymmetry: most left-handers, left dominant for language, display either bilateral or right hemisphere language dominance compared with right-handers. To examine the influence of language lateralization on humor processing, researchers conducted an ERP study with left-handed and right-handed participants reading three stimuli: jokes, straights (with a cloze-matched non-joke-ending) and filler sentences. For right-handedness participants, jokes had positive activation between 500ms and 900ms, largest over right centro-parietal regions, and a slow sustained negativity over left anterior lateral area; for the left-handedness participants, jokes also had positive activation between 500ms and 900ms, but larger and more broadly distributed than in the right-handedness ERPs; in right-handedness female, the late positivity was larger over right hemisphere, while in left-handedness women, the late positivity was bilaterally symmetric; the highly asymmetric slow sustained negativity over left anterior area was not found in left-handedness' ERPs in jokes, with the differences reflecting more efficient inter-hemispheric communication in the left-handedness people, as they have relatively larger corpus callosal areas than right-handers, suggesting more bilateral language representation among left-handers, with language lateralization affecting high-level language comprehension tasks such as joke comprehension (Coulson and Lovett, 2004).

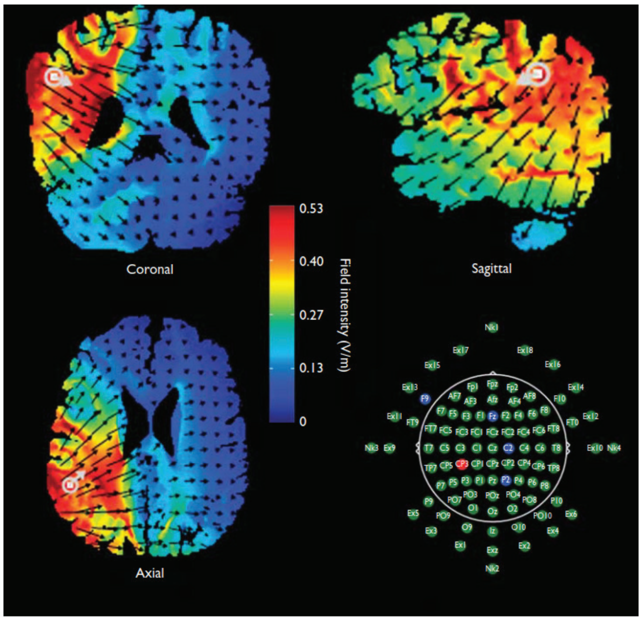
To further study the relationships between hemispheric asymmetries and joke comprehension, researchers again employed ERPs to conduct experiments by using one-line jokes with punch words and nonjokes as the stimuli. Jokes had more activation in N400 than nonjokes when appearing in the right visual field and processing in left hemisphere. Jokes and nonjokes activated two hemispheres equally when appearing in left visual field and processing in right hemisphere. These findings indicated that semantic activations in the two hemispheres do differ, with right hemisphere semantic activation facilitating joke comprehension (Coulson and Williams, 2005).

Another study was conducted to explore the correlations between different stages in humor processing (incongruity detection, resolution and elaboration) and readers' surprise, comprehensibility and funniness levels. The analysis results indicated that highly surprised group had greater activation in N400; good comprehenders elicited a larger P600; the high amused group had a greater activation for the late positive potential. In addition, the different degrees of surprise, comprehensibility and amusement to jokes influenced three stages respectively in humor processing (Ku et al., 2017).

In short, due to the complexity of humor, besides social factors and psychological factors, cognitive factors and biological factors also have great influences on humor appreciation, such as comprehension level, handedness, hemisphere asymmetry etc., which results in different degrees of humor comprehension and even slightly different neural mechanism in humor appreciation.

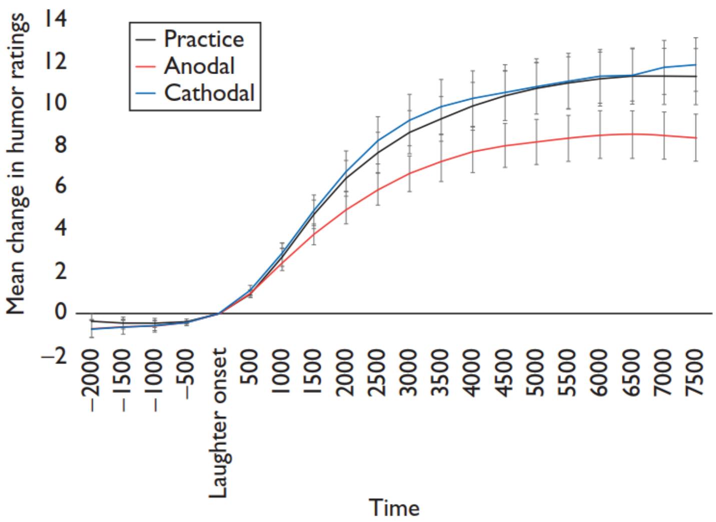
To investigate the effects of current stimulation in improving humor appreciation

A great number of researches have demonstrated that certain brain regions can be activated by humorous stimuli, but there has been very little research exploring whether the humor appreciation will be improved by stimulating relevant brain regions. A study evaluated the influence of transcranial direct current stimulation targeting the left temporo-parietal junction on humor appreciation during a dynamic video-rating task (Slaby et al., 2015) (see Fig. 24). Researchers targeted the left temporo-parietal junction with either anodal / cathodal or no transcranial direct current stimulation and centered at electrode site C3 using a 4×1 targeted stimulation montage; during stimulation, participants dynamically rated a series of six stand-up comedy videos, with the data showing that anodal stimulation decreased humor ratings over time (see Fig. 25) and individual differences showed some limited values in predicting this pattern. In sum, neuromodulation of the left temporo-parietal junction can alter the mental processes underlying humor appreciation, suggesting critical involvement of this cortical region in detecting, comprehending and appreciating humor (Slaby et al., 2015).



Predicted direct current propagation through the left temporoparietal junction at 2.0 mA intensity using the finite-element model provided in the HDTargets (Soterix Medical Inc.) software. Also shown is the arrangement of electrodes (lower right); for anodal stimulation, red is the anode and blue are cathodes (returns), and for cathodal stimulation, red is the cathode (return) and blue are anodes.

Figure 24 Predicted direct current propagation through left temporo-parietal junction (Slaby et al., 2015)



Mean change in humor ratings over time, for all five analyzed videos, as a function of stimulation condition.

Figure 25 Mean change in humor ratings over time (Slaby et al., 2015).

Another study explored whether Transcranial direct current stimulation (tDCS) application to the STG (Superior Temporal Gyrus) would modulate the ability to recognize and appreciate the comic element in serious and comedic situations of misfortune. It found that a condition of Anodal-left / Cathodal-right stimulation improved the mean reaction time in response to both Comic and No Face stimuli, while a condition of Anodal-right / Cathodal-left stimulation improved the mean reaction time specifically for Comic compared to sham stimuli. These results confirmed that modulation of the STG appeared to affect the processing of humorous situations and suggested a functional hemispheric asymmetry in STG response to social stimuli. The study demonstrated that the superior temporal gyrus formed part of the complex network involved in humor processing. Indeed, the data suggested that STG stimulation improved the ability to recognize and appreciate humorous slapstick scenes. In particular, the left STG might have a role in global processing of a social complex situation, while the right STG may be involved in the ability to efficiently recognize and integrate specific emotional components (facial expression) in a complex scene (Manfredi, 2017).

5.3.1.3 Frequency dimension

Svebak (1982) explored the effect of mirthfulness upon the amount of discordant right-left occipital EEG alpha production by using a comedy film as the stimuli. The findings revealed that there was less discordant alpha in the right hemisphere for the subjects who laughed at the comedy film, and by contrast, for the people who didn't laugh, the discordant alpha increased in this hemisphere.

A study adopted the recall of humorous videos as the stimuli by using the equipment of Brain Computer Interface system with a 14-channel headset connected to a USB receiver, which can be used in any conventional personal computer allowing time serial data to be transmitted for both online and offline analysis. The results suggested the existence of significant beta activity when subjects recall humorous thoughts and furthermore, and the recall of humorous moments elicited statistically significant changes in EEG signals in the bands of 24Hz-28Hz and 28Hz-32Hz for the channel of T7 (close to anterior temporal lobe) and for the channel of P7 (close to inferior parietal lobe) (Ramaraju et al., 2015).

Another study manipulated the head portraits of celebrities as the humorous stimuli and found that the significant differences were presented particularly in the right prefrontal and frontal areas. Analysis of event-related spectral perturbation showed significant differences in the theta band evoked in the anterior cingulate cortex, parietal region and posterior cingulate cortex, in the alpha and beta bands in the motor areas, involving in emotional processing, memory retrieval and laughter and feelings of amusement induced by elaboration of the situation (Wang et al., 2017).

5.3.1.4 Multimodality dimension

To investigate the psychological and physiological processes in verbal humor processing, researchers utilized psycho-physiological measures of heart rate and facial electromyography (EMG) in experiments. They found that heart rate acceleration of jokes was greater than non-jokes and was positively correlated to humor appreciation; in addition, zygomaticus activity was greater for jokes relative to nonjokes; jokes compared with non-jokes activated a decreased heart rate response at the initial inflection point (the zygomatic EMG response occurring during the initial heart rate deceleration phase as a marker for the onset of humor comprehension), revealing a notion that the start of the humor response, or a psychological moment of insight, was always associated with heightened cardiovascular activity (Fiacconi, 2015).

5.3.2 From the perspective of different types of humor

Humor, as a communication tool, can be presented in many different types, such as jokes, cartoons, comedy movies, slapsticks, stand-ups and so on. For cognitive process of humor appreciation, different stimuli have different neural pathways in the brain. For example, comic pictures activate visual areas in the brain, located in the occipital lobe, and by comparison, when people listen to a joke, the auditory areas of the brain are activated, located in the temporal lobe.

A study investigated different neural mechanisms of two different types of humor: sight gags (visual humor without words) and language-based humor. The findings revealed that the processing of sight gag humor showed increased activation in higher order visual regions bilaterally when compared with language-dependent humor. Whereas language-dependent humor was located in left-lateralized temporal and frontal cortices compared with sight gag humor. Besides, the results also highlighted a common network elicited by both types of humor, including the amygdala and the nucleus accumbens, which were closely related to the affective response to humor appreciation. In general, the brain networks being recruited during a humorous experience differ according to the specific type of humor being processed (Watson, 2007).

5.3.2.1 Verbal humor

Originating from different structural levels of language, verbal humor can be presented in different forms, such as phonetic jokes, semantic jokes, syntactical jokes etc. For verbal humor task, damage to the right hemisphere affected humor appreciation. The individuals with damage in right frontal lobe reacted less, with diminished physical or emotional responses due to the function of information integration in the right frontal lobe (Shammi and Stuss, 1999). In addition, verbal humor appreciation deficit was also significantly related to the deficits in frontal functions (Shammi, 2000). Goel and Dolan (2001) indicated that semantic jokes and phonological jokes required different neural networks. In detail, the semantic jokes involved the activation of bilateral temporal lobe network, while the phonological jokes involved the activation of a left hemisphere network focusing on the speech production regions. Chan et al

(2012) indicated that both bilateral inferior frontal gyri and left superior frontal gyrus were related to verbal humor comprehension, while the cortical region in left ventromedial prefrontal cortex and the subcortical regions in bilateral amygdala and bilateral parahippocampal gyri were connected to the affective element or mirth in verbal humor processing. In another study, same researchers (Chan et al., 2013) further isolated the two elements of verbal humor comprehension: incongruity detection and incongruity resolution. The findings indicated that, in verbal humor, right medial frontal gyrus was greatly elicited due to the incongruity detection; and left inferior parietal lobule was greatly elicited due to the incongruity resolution.

5.3.2.2 Nonverbal humor

Nonverbal or cartoon humor is related to cognitive processes of working memory, visual search and scanning, mental flexibility and visual directed attention (Shammi, 2000). In cartoons, the triggers for the various stages of cognition are distributed not strictly linearly as in joke texts, but are spatially arranged, even across the modes of picture and text and as a result, the processes may be more easily teased apart operationally and, consequently, empirically into various constellations of stages and their successions than it is possible in verbal humor (Hempelmann and Samson, 2008).

Mobbs et al. (2003) employed funny and nonfunny cartoons as the stimuli in analyzing humor appreciation. The findings revealed that, compared with nonfunny cartoons, funny cartoons were activated in the left temporo-occipital junction, interior frontal gyrus extending to temporal pole, and supplementary motor area, extending to dorsal anterior cingulate. A subcortical cluster also was observed encompassing the ventral striatum / nucleus accumbens, anterior thalamus, ventral tegmental area, hypothalamus and amygdala. Moran et al. (2004) conducted an fMRI experiment by employing dynamic, real-life content as the stimuli: TV sitcoms “Seinfeld” or “The Simpsons”. Humor detection revealed increases in left inferior frontal and posterior temporal cortices, whereas humor appreciation revealed increases in bilateral regions of insular cortex and the amygdala. Bartolo (2006) conducted a study using cartoons as stimuli and the findings revealed that inferior frontal and middle temporal gyrus of the left hemisphere played a key role in humor detection. Both hemispheres (right inferior frontal gyrus, left superior temporal gyrus, left middle temporal gyrus and left cerebellum) were activated during the process of the incongruity resolution.

Samson (2008) included three types of cartoons in the experiment: visual puns (visual resemblance), semantic cartoons (pure semantic relationships) and theory of mind cartoons (requiring additionally mentalizing abilities). With a left-sided network being suggested to be involved in semantic cartoons for pure incongruity resolution: e.g. temporo-parietal-junction, inferior frontal gyrus and ventromedian prefrontal cortex, which were also closely correlated with the processing of theory of mind cartoons, whereas visual puns showed more activation in the extrastriate cortex and theory of mind cartoons showed more activation in mentalizing areas. A four-frame manga, including introduction, development, turn and conclusion (punch line), was used in the experiment. From the "development", activation of the temporo-parietal junction was observed, followed by activations in the temporal and frontal areas during viewing the "turn". For the "conclusion", strong increased activations were confirmed in the medial prefrontal cortex and cerebellum (Osaka et al., 2014).

Another study investigated the different neural mechanisms of sight gags and language-based humor. The findings revealed that sight gag humor elicited increased activation in higher order visual regions bilaterally when compared with language-dependent humor. Whereas language-dependent humor was located in left-lateralized temporal and frontal cortices compared with sight gag humor. Besides, the results also highlighted amygdala and the nucleus accumbens elicited by both forms of humor, closely related to the affective response to humor appreciation (Watson, 2007).

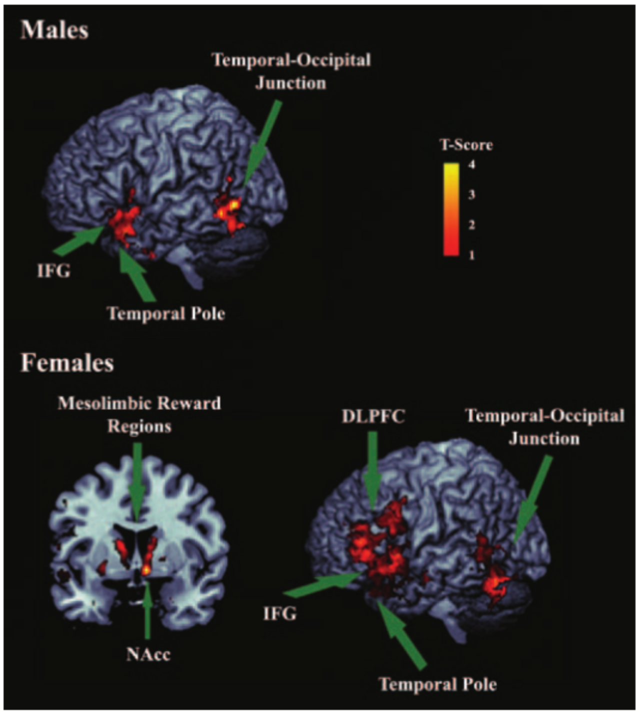
In sum, different types of humor have different neural mechanisms in their cognitive processes, though all types of humor share the same processing stages, such as incongruity detection, resolution and mirth. During the incongruity detection, for verbal humor, the relevant language brain regions are activated, and for nonverbal humor, the visual search is spatially arranged, which elicits the visual brain regions. Then going into the incongruity resolution, more complex processing is involved so that more brain regions related to attention, memory, problem-solving etc. are activated for both verbal humor and nonverbal humor. In the stage of mirth, all types of humor activated affective responses, which is mainly correlated with reward system in the brain.

5.4 Gender differences in cognitive process in humor

In a study on children's humor, although young children of both genders were comparably able to express and appreciate humor at home, gender differences were reported in the amount of humor, with girls laughing more; but in school, with boys more often being the humor "actors" and girls more often being the "audience" (Canzler, 1980). In a child-sibling pairs study, Vrticka et al. (2013a) used color video clips as stimuli and fMRI as the experimental tool to show that sex differences in humor appreciation already existed in young children (13-16 years old). The results revealed that increased activity to humor stimuli occurred in bilateral temporo-occipital cortex, midbrain and amygdala in girls, which reflected the presence of early sex divergence in reward saliency or expectation and stimulus relevance attribution.

Some early research suggested there were gender differences in the degree to which the right and left hemisphere of the brain were predominantly used in processing humorous material (Martin, 2014). But some studies failed to replicate the differences on lateralization in humor processing between males and females. For example, Gallivan (1991) conducted a behavioral study to indicate that, for both men and women, the humor perception activated more in right hemisphere more than in left hemisphere, leading to the doubts on different lateralization in humor processing between the male and the female.

Although men and women do not seem to differ in brain lateralization in responses to humor, there are some more recent brain imaging research suggesting that other parts of the brain may be differentially activated in men and women when processing humorous materials (Martin, 2014). Researchers used event-related fMRI to investigate the relationships between gender difference and neuroanatomical correlates of humor appreciation. Both selected verbal and nonverbal cartoons were grouped into funny and nonfunny stimuli and the data were analyzed according to BOLD signal activation. The results showed that both female and male had some common brain regions activated in humor processing, such as temporal-occipital junction, temporal pole and inferior frontal gyrus, relevant to language processing. But females had greater activation in left prefrontal cortex and mesolimbic regions at the right nucleus accumbens more than males, which revealed that females had greater degree in language comprehension and greater degree in reward network than males in humor appreciation (Azim et al, 2005) (see Fig. 26).

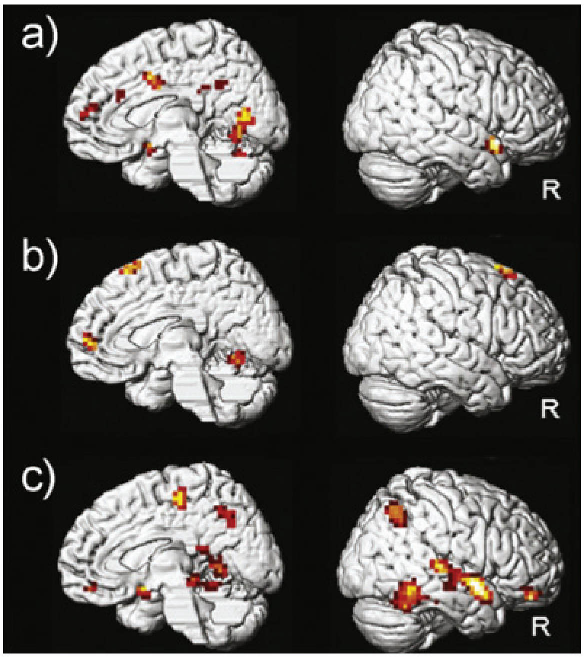


Males demonstrate cortical activation of the temporal-occipital junction, the temporal pole, and superior temporal gyrus (STG), as well as the inferior frontal gyrus (IFG). Females show activation of the temporal-occipital junction, temporal pole and STG, extending into dorsolateral prefrontal cortex (DLPFC), IFG and middle frontal gyrus (MFG), as well as subcortical dopaminergic reward regions, including the nucleus accumbens (NACC).

Figure 26 The differences between males and females on BOLD signal activation for funny-unfunny cartoons (Azim et al., 2005)

A study examined whether cartoons created by female / male cartoonists differ in the formal features and found that, from the perspective of humor creation, men draw more cartoons with nonsense humor, whereas women draw more incongruity-resolution cartoons (Samson, 2007). Another study used BOLD contrasts to examine the commonalities and differences in neural substrates of humor processing between genders. The findings suggested that, for comprehension part of humor processing, both men and women shared similar activations in brain regions, but for emotional part, there was significant gender differences: women had greater activation association between affective rating and ventral emotion processing system, including amygdala, insular and anterior cingulate cortex, while men showed activation in both ventral and dorsal processing systems, with the function to modulate the activation of amygdala and insula (Kohn, 2011) (see Fig. 27).

To sum up, though there are experiments having doubts on the gender difference in the cognitive process in humor appreciation, there are more experiments demonstrating the existence of it. The main difference between males and females in humor processing lies in the reward system in the brain, such as amygdala, insular and anterior cingulate cortex, which are responsible for the affective response in humor appreciation.



a) brain activation in cartoon in women; b) brain activation in cartoon in men; c) brain activation from the direct contrast from cartoon in women vs men.

Figure 27 The difference of brain activation between genders in humorous cartoon processing (Kohn, 2011).

5.5 Cognitive process in humor over a lifespan

As a social behavior, humor has survival values for infants, enhances cognitive and linguistic development of children, deflects aggression and facilitates communication among adults, helpful for the formation of peer group identity and affiliation, with its values, across infancy, childhood and adolescence, have been empirically demonstrated (Simons et al., 1986). Since the previous content is devoted to the analysis on humor processing during adulthood, the following content will then introduce humor processing in the context of life span. Humor appreciation is different at different stages in the life time for each individual (Raskin, 2008), which leads to the developmental changes of humor processing across different life phases.

5.5.1 Children's humor processing

An early source of theoretical rationale of humor appreciation among children came from Freud (1960b), who posited that children's cognitive and emotional development were tied to their humor development, particularly in regard to their emerging ability to joke. If the scholars limited the understanding of "humorous communication" to "linguistic humor" (that begins when language emerges at age 9—12 months), communication researchers' lack of attention to humor in infancy made sense (DiCioccio et al., n.d.). But they neglected other forms of humorous communication, such as laughs, chuckles, tickles and so on. Infants' smiles appear as early as age 2-months (Dickson et al., 1997). Researchers have proposed that, among the instinctual responses, smiling is a very important one that links the infant with the mother and the mother with the infant in a reciprocal dynamic, helping the infant to survive and reproduce in adulthood (Bowlby, 1958). For the infants less than 6 months of age, the tactile and auditory stimulation are the significant stimuli for laughter elicitation, but when infants progress beyond 6 months, the visual and social stimuli will be in dominant position for laughter elicitation. Laughter first occurs when playing with infants either by their voices, facial expressions or body contact, such as tickling, peek-a-boo games or unusual facial expression and sounds, which produce relatively high rates of laughter until 7 or 8 months, and then visual and social actions are more likely to induce laughter at 12 months (Martin, 2010). Thus, humor expression is a function of how the infant and environment continue to adapt to one another (Simons et al., 1986).

The ability to comprehend and appreciate humor actually corresponds with children's social, cognitive and emotional development. Humor development, in the form of social looking, roots in the play with caregivers and develops in the play with peers. Thus, humor originates from play. In essence, the laughter in infants is caused by the surprising or incongruous component embodied in the interactions with their caregivers. For example, the peek-a-boo, a very typical game, greatly amusing infants because of their caregivers' sudden appearance in different locations, is beyond their expectations and triggers the primitive type of incongruous detection and resolution. For 6-month-old infants to 12-month-old-infants, they experience qualitatively different kinds of enjoyment during the games of peekaboo or tickle: enjoyment of readiness to engage in play, enjoyment of relief, enjoyment of participation and agency, enjoyment of escape and enjoyment of buildup (Fogel, 2000.).

Shultz (1976) believed that the laughter and smiling accompanying the games, such as peek-a-boo, tickling and chasing, are considered to constitute early forms of humor because they share the sequence of arousal increases followed by arousal decreases, which are hypothesized to occur in the identification and resolution of incongruities among older children and adults. However, McGhee disagreed with Shultz' contention that infants are capable of experiencing humor in the first year. He argued that the experience of humor requires the capacity for assimilating events in a fantasy or make-believe sense, which does not occur until sometimes in the second year (McGhee, 1977). Another study also aimed at the humor perception in 6-12-month-old infants, revealing that when parents provided unsolicited affective cues during a humorous event, 6-month-olds employed social looking from their parents: for example, if they did not laugh at the event, they were more likely to look towards parents and smiled at their parents; but by 12 months, infants were more likely to smile at the event (Mireault, 2014). As a result, infants' laughter is actually a social communication form, which takes place during interactions with the caregivers, who respond back to the infants with their laughter.

After children enter the nursery schools, their laughter increases when they are playing with other children besides their parents or caregivers (Martin, 2010). Humorous or playful behaviors are one way children can cope with the conflict and maintain a bond with others while simultaneously breaking free from the bind (Simons et al., 1986). With the development of children's social, cognitive and emotional capabilities, their humor appreciation also upgrades to a relatively complicated stage, from nonverbal actions to verbal behaviors, and things that were funny to the infants doesn't work when they grow into a later age.

Based on the theoretical propositions of Jean Piaget (1960), who is a well-known Swiss psychologist, Paul McGhee (1979) proposed that children's increasing cognitive ability to perceive incongruity is the basis of humor development. Then he developed a theory indicating four stages of humor development in childhood, which progressed along with the improvement of cognitive abilities, including incongruous actions towards objects, incongruous labeling of objects and events, conceptual incongruity, and humor in multiple meanings. Afterwards, McGhee (2002) revised it to a comprehensive stage-model of children's developmental humor appreciation: perceiving incongruity in infancy, producing incongruity nonverbally in toddlerhood, producing incongruity verbally in early childhood and presenting incongruity and resolution. This model can go on along with four stages:

Stage 1. laughter at the attachment figure;

Stage 2. treating an object as a different object or misnaming objects or actions;
Stage 3. play with words;
Stage 4. riddles and jokes

to show a more clarifying picture about the stages of humor development in the phase from infancy to childhood (see Table 2).

Table 2 Stages of humor development in children (McGhee, 2002)

Stages of Humor Development				
stage	age	cognitive processing	embodiment forms	Examples
stage 1	about 6 months	perceiving incongruity by being aware of the interpersonal surroundings	laughter at the attachment figure	peek-a-boo games
stage 2	about 2 years old	producing incongruity nonverbally: incongruous labeling of objects	treating an object as a different object	a child holds a stick to her mouth as if it were a spoon
stage 3	about 3 years old	producing incongruity verbally: conceptual incongruity	making up silly words	a child calls a hand a foot
stage 4	about 7 years old	presenting incongruity and resolution:multiple meanings	appreciating more sophisticated humor in more complex ways	riddles and jokes

Based on McGhee's theory, a study investigated the explanations of kindergarten children (ages 5-5.5) on pictorial humor. The results suggested that kindergarteners, boys and girls, were equally capable of recognizing and explaining the main and minor incongruities in funny pictures (Loizou, 2006). Again, same researchers did another experiment (Loizou, 2016) to investigate children (3-7 years old) about their humor appreciation and humor creativity. The results revealed that children aged 3-7 years can appreciate the humorous aspects of a picture and can explain the reasons by recognising the main incongruity and resolution to provide a funny explanation.

When children develop into elder age, they will not enjoy the same humorous stimuli like what they did when they were younger, which doesn't mean that children's enjoyment or appreciation of humor decreases with growing up, because humorous material that is moderately complex and stimulating for a child at a given developmental level tends to receive the most appreciation (Brodzinsky, 1975).

In order to illuminate the neural network involved in the detection and appreciation of humor in childhood, Neely (2012), for the first time, studied children (6-12 years old) as the subjects by using fMRI. Video clips, categorized into three conditions: funny, positive (enjoyable but not funny) and neutral (not intended to evoke any emotional responses), were used as the stimuli. The results revealed that humorous stimuli activated the temporo-occipital-parietal junction and mesolimbic area in children, which suggested that the neural network already exist in childhood. When compared with positive stimuli, funny stimuli specifically elicited the activation in temporo-occipital-parietal junction, which was closely related to humor processing. Besides, younger children's greater activation in the inferior frontal gyrus and nucleus accumbens suggested that they put more efforts into the humor processing and get more enjoyment from it, which was closely in line with the degree of their cognitive development.

In the previous part, the experiments showed the interacting relationships between personality and cognitive process in humor appreciation among adults. To investigate the situations among children, a study by fMRI firstly attempted to illustrate on effects of traits of characters on brain activity in humor appreciation among children (6 -13 years old). Considering the limitations of reading abilities of children, video clips were selected as the stimuli. The findings indicated that the activation in temporo-occipito-parietal areas and the mesocorticolimbic dopaminergic circuits in humor appreciation were mediated by the degree of factors of temperament, corresponding to neuroticism, fear and extraversion in adults. The results indicated that, among children, emotionality had positive correlations, but shyness had negative correlations with brain activity connected to both cognitive and humorous abilities; shyness and sociability were positively related to the activity in the periaqueductal gray region during humor processing; age and IQ were also related to greater activation in the cognitive component of humor processing (Vrticka et al., 2013b).

It is important to note that the researchers have also found wide interindividual differences in humor expression and appreciation among children of the same age (Masten, 1986), which has close relations with different elements in children's development background, such as cognitive element, social element and affective element, influenced by the brain development. For example, amygdala volume increased with age significantly only in males and hippocampal volume increased significantly with age only in females (Giedd et al., 1996). In addition, with the increasing of the age, the range of humor types enjoyed by children is also expanded, without any types of dropping out, but young children enjoy humor types that are completely different from those appreciated by the older (Bergen, 1998).

5.5.2 Adolescents' humor processing

The general findings from Prerost (1982) indicated that growing inhibits the adolescent's perception of joking humor, beginning in the middle adolescence (16 years old) and extending into late adolescence (19 years old). Scholars suggested that what adolescents saw as the most humorous was related to their ongoing attempts to master current developmental task, which implicated a cognitive link between the adolescent's ability to master developmental tasks and the ability to produce and consume humor (Simons et al., 1986). Children of middle adolescence are faced with both psychological and physical changes, connected to the general social and cognitive processes, which, to a great degree, have impacts on their humor appreciation. For example, jokes and cartoons that match their developmental maturity are perceived as funny, while jokes that are too advanced are threatening (Simons et al., 1986).

A study revealed that incongruity-resolution humor increased in funniness and nonsense humor decreased in funniness among progressively older subjects after the late teens (Ruch et al., 1990). Humor appreciation is an index of growth and sense of humor is a source of the change, a vehicle whereby the environmental context socializes and brings adolescents closer to the culture's expectations of adult functioning. And it is also a tool for the adolescent children who use humor in the service of transforming the environment. Through the process of mutual socialization from the infancy to the adolescence, humor is described best as a developmental phenomenon that is conductive to successful interactions between the growing human organism and the culture's social contexts (Simons et al., 1986). Besides, the employment of different styles of humor influences the perceived social support for adolescents, indicated by a study: self-enhancing humor plays a key role in achieving social support for adolescents (Karakuş et al., 2014).

5.5.3 Normal aging on humor appreciation

Biological evidence indicated that most functions of people decline with aging, including the functions of the brain. Global changes in aging brain can be found at almost any level of observation and amongst different brain regions, with frontal functions being the first to deteriorate with aging (Raz, 2000). Moreover, there is a growing recognition that some functions mediated by the frontal lobes may be particularly vulnerable to change with aging (Moscovitch and Winocur, 1992). Besides, imaging studies indicated that structural and chemical changes continued in frontal lobe with aging, and neuropsychological investigations also suggested a decline in certain functions mediated by the frontal regions as a consequence of normal aging (Shammi, 2000).

The frontal regions are commonly considered to be closely related with the cognitive abilities, including mental flexibility, abstract thinking and working memory, which are also key to humor appreciation. In contrast to younger adults, older adults have greater difficulty with humor comprehension because their cognitive abilities gradually decrease. Verbal and nonverbal humor comprehension tests, cognitive flexibility tests, abstract reasoning and short-term memory were made between the younger and the older, which showed that older adults had lower scores than younger adults on tests of both humor and cognitive abilities (Mak and Carpenter, 2007). Thus, humor appreciation is, to great extent, influenced by normal aging.

The experiments conducted by Shammi (2000) revealed that the cognitive ability and joke comprehension of elderly people began to decline with aging, and the increase in the cognitive demand of the joke led to greater appreciation, explaining why the funniness ratings on the humorous stimuli of elderly people were higher than younger people. To investigate the relationship between normal aging and humor appreciation, a review study (Greengross, 2013) suggested that elderly people enjoyed humor more than younger people, but they had increasing difficulties in understanding jokes, and the amount of laughter exhibited by the elderly was smaller compared with younger adults. For humor styles, the elderly did not prefer aggressive styles of humor and they were very sensitive to the jokes related with old age.

Researchers (Shammi and Stuss, 2003) also investigated the normal aging functions on humor appreciation by examining the correlations between verbal and nonverbal humor appreciation, and measurements on working memory, mental flexibility and abstract thinking. The experiment found that there was no difference between younger and aged people in rating the humorous stimuli. In the contrast between the elderly and the patients with focal frontal lesions, the findings suggested that the elderly displayed intact appreciation of humor or affective responsiveness although they were aging, underlying the success reported in the elderly's using humor as a coping mechanism to adapt to stressful situations. However, in punch line selecting in joke appreciation and in a cartoon array test, which was associated with more complex task, the difference between the young and the aged became significant. Since the processing of more complex tasks was closely related to the frontal lobe, the study revealed that the age-related decline in frontal lobe cognitive abilities had great influences on the humor processing (Shammi and Stuss, 2003).

To respectively investigate the impacts of normal aging on cognitive and affective components in humor appreciation, researchers (Uekermann et al, 2006) conducted an experiment by examining their relationships with mentalizing and executive skills: the stimuli of the experiment were the joke stems followed by four different endings: funny ending, a slapstick ending, an illogical ending and a logical ending; subjects were required to rate the funniness and logic for each ending they selected. To record the mentalizing responses, each subject was asked to explain the jokes after the presentation of the jokes, including the joke stems and their corresponding funny punch lines; the results showed that though aged people were able to choose the correct funny punch lines, but the accuracy was much lower than younger adults and they selected more logical endings and slapstick endings instead, because they tended to find the correct funny endings were less logical compared with the results from younger people. Besides, in mentalizing and executive tasks, aged people had much lower scores compared with younger adults, which was closely related with their mentalizing deficits and executive impairments. The findings implied that aged people differed from younger adults both in cognitive component, reflected in the lower accuracy rate in selecting correct funny endings, and affective component humor as well, reflected in their lower scores for funniness ratings in the experiment.

5.6 Neural mechanism of Chinese verbal joke processing: A Pilot Study

Since most of the humor-processing studies were based upon alphabetic language, which was elementarily different from Chinese characters, I conducted a pilot study by ERPs to specifically investigate the cognitive process of Chinese verbal jokes for the promotion of the design concept used in different languages. Besides, this pilot experiment, currently aiming at adults, was the first step of the study on the cognitive process in humor appreciation over a life span and the future experiments would focus on children and aged people.

5.6.1 Research objectives and hypothesis

This pilot study was the first step of a lifespan research serving the emotion design concept in this monograph. Since age has great effects on humor appreciation, the neural mechanisms of humor appreciation will also be different for people across different life phases. There are some behavioral studies demonstrating the distinctiveness among people with different ages in humor appreciation, but it lacks the objective evidence deriving from brain imaging method. In order to propose the emotion design concept combining with neuroscience research, the study on the influences of lifespan on cognitive humor processing was indispensable, which not only formed the foundation of the evaluation of the mental states, but also built up the grounds for setting standards in the intervention. The current experiment only involved adults by far, and future experiments will cover a whole life span: childhood (8 -12 years old), adolescents (13-17 years old), young adulthood (18-40 years old), late adulthood (41-65 years old) and old age (66 to up).

What's more, most of the findings in previous research are on the basis of alphabetic language, whose processing mechanism is actually different from Chinese characters, because Chinese characters consist of both phonological radicals and orthographic radicals. Liu and Perfetti (2003) indicated that at 150ms, Chinese produced earlier and higher amplitude than English. Besides, Huang et al., (2014) suggested that P200 is a sensitive electrophysiological index of early phonological processing independent of semantics in Mandarin Chinese spoken word recognition. Kong et al. (2012) presented clear evidence that P200 is sensitive to orthographic similarity modulated by orthography alone in reading Chinese word. Since the basic neural mechanisms of processing Chinese characters and processing alphabetic words are distinct from each other, the mechanisms of processing Chinese verbal jokes and alphabetic verbal jokes will also be different. I hypothesized that, apart from similarities in common neural mechanism of humor processing for both alphabetic language and Chinese, there will be specific features in Chinese verbal joke processing.

5.6.2 Experiment Procedure

5.6.2.1 Subjects

As paid volunteers, a total of 30 right-handed adults (15 male, 15 female) with normal, or corrected-to-normal vision, aged 19 to 28 years (mean age: 23.75 years), from Dalian University of Technology, China, and Liaoning Normal University, China, were recruited to take part in this experiment. All participants were free of neurological and psychiatric diseases. They were all consent with following the directions during the experiment and had been informed of instructions of all procedures before the experiment. Subjects were asked to minimize their movements and eye-blinks during the experiment. In the phase of preprocessing, 6 participants were removed due to the invalidity of their data, thus 24 participants' data were remained and analyzed. Considering the subjects with different ages in the future experiments, children and old aged people cannot sit in the front of the computer for the test for long time, which will cause the fatigue of the subject and influence the data results, so I randomly grouped three participants into one subject to reduce their length of time of doing the experiments. Thus, 24 participants were randomly divided into 8 groups and in the phase of ERPs data analysis, these 8 groups of participants were regarded as 8 subjects (every 3 participants shared the same punchlines, though the set ups they saw in the experiments were different). In this way, reviewing effects caused by the same stimulus can also be avoided.

5.6.2.2 Material

Before the experiment, 90 question-answer type Chinese jokes were selected from either the internet or books. After the pretest among 150 people (different from the subjects in this experiment), top 60 jokes which were ranked as funny were subsequently selected, together with 60 nonjokes (from the internet and newspapers) and 60 produced nonsensical sentences, 180 experimental sentences in total, were used as stimuli in this experiment.

The setup sentences instead of punch lines of jokes were controlled to avoid that the neural activities were triggered by different punch lines. Every set of stimuli consisted of three different conditions: joke, nonjoke and nonsensical sentence, which shared the same punch line. All stimuli sets were randomly divided into three blocks and every participant can only see one block for one stimulus type, so the same punch line would never be seen twice for each participant. Nonjokes were all related to semantic memory from daily life and nonsensical sentences were all kept at a very low semantic level. Each set up sentence was limited to 15 Chinese characters and each punch line was limited to 2-4 Chinese-character words (see Fig. 28 about one of the examples of a set of stimuli).

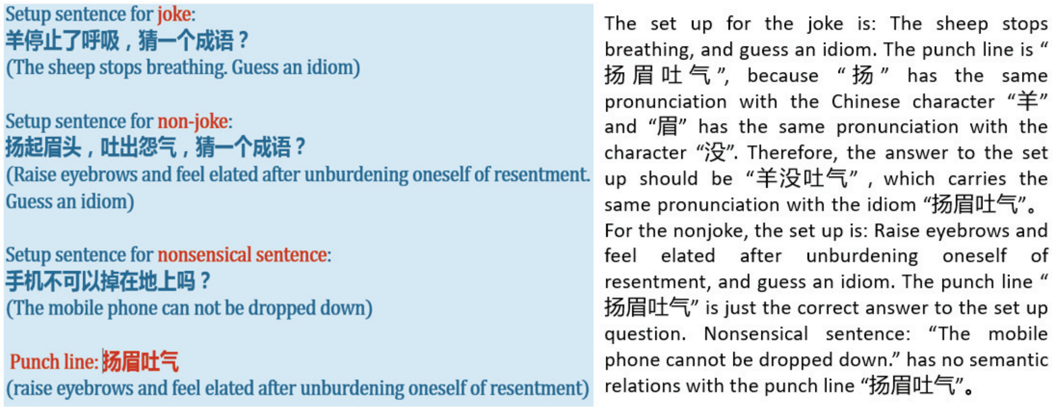


Figure 28 The example of a set of stimuli consists of three conditions: joke, nonjoke and nonsensical sentence.

5.6.2.3 Data collection

The current experiment employed Event-related Potentials (ERPs) as the experimental method, because ERP technique will shed light on temporal processing of humor and validate theoretical models like incongruity-resolution (Rozengurt, 2011). E-Prime software was used to design the procedure of the experiment. Participants were seated in a quiet room and a screen was placed approximately at 100cm from them. They were instructed to become familiar with the procedure and pace before the experiment. Five trials using the same procedure as in the formal ERP experiment were presented to the subjects beforehand. The flow of stimuli presentation in each trial was shown in Fig. 29.

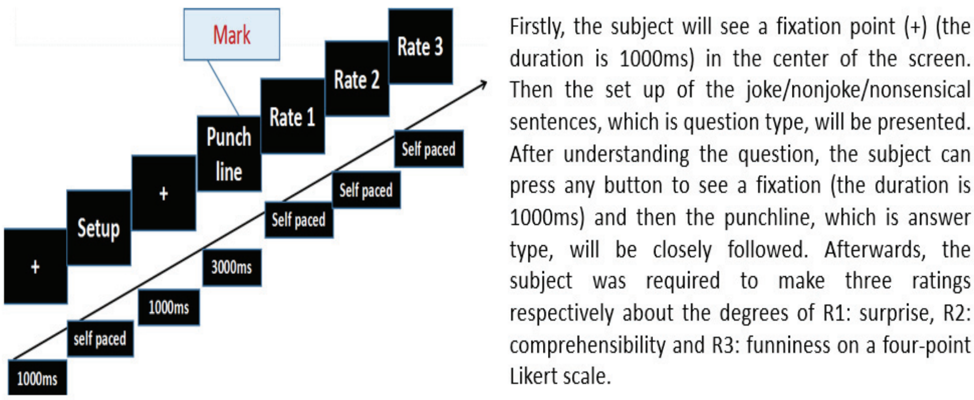


Figure 29 The flow of stimuli presentation in each trial.

During the experiment, brain electrical activity was recorded from 64 scalp sites using electrodes fixed in electrode cap with the reference on the left and right mastoids. The EEG signal was amplified with a band pass from 0.05 to 70Hz using the amplifier of Neuroscan, Inc. All interelectrode impedance was maintained below 5kΩ. ERP wave forms were time-locked to the onset of the punch line. Trials, contaminated with artifacts, such as excessive vertical or horizontal electro-oculographic potentials, excessive muscle activity, bursts of electromyographic activity, or peak-to-peak deflection exceeding ±100 mV, were excluded from averaging. The averaged ERP epoch was 2000ms and included a 100ms pre-solution baseline. All epochs were band pass filtered in the range of 0.1-30 Hz using digital, zero-phrase shift filtering.

Four time windows: 150-220ms, 350-500ms, 500-700ms, and 800-1500ms were emphasized to dissociate different stages of humor processing: preprocess of incongruity detection, incongruity detection, incongruence resolution and emotion release.

5.6.3 Behavioral results

5.6.3.1 Results of ratings

Pair t-tests were performed on rating scores among jokes, nonjokes and nonsensical sentences for surprise, comprehension and funniness ratings respectively, with the sig. (2-tailed) = 0.000. In funniness ratings, the scores of jokes were higher than nonsensical sentences and nonsensical sentences were higher than nonjokes (for example, see Fig. 30, funniness block 1: joke (2.625) > nonsensical (1.8813) > nonjonke (1.6375); the column of joke was obviously higher than nonsensical sentences and nonjokes). In comprehensibility ratings, the scores of nonjokes were higher than jokes and jokes were higher than nonsensical sentences (for example, see Figure 30, comprehensibility block 2: nonjoke (3.275) > joke (3.075) > nonsensical sentences (1.7375); the column of nonjoke was obviously higher than jokes and nonsensical sentences). In Surprise ratings, the scores of nonsensical sentences were higher than jokes and jokes were higher than nonjokes (for example, see Figure 30, surprise block 3: nonsensical sentence (3.3563) >jokes (2.8063) > nonjokes (1.6125); the column of nonsensical sentences was obviously higher than jokes and nonsensical sentences). All these results were in line with the expectation, demonstrating the typicality of selected stimuli.

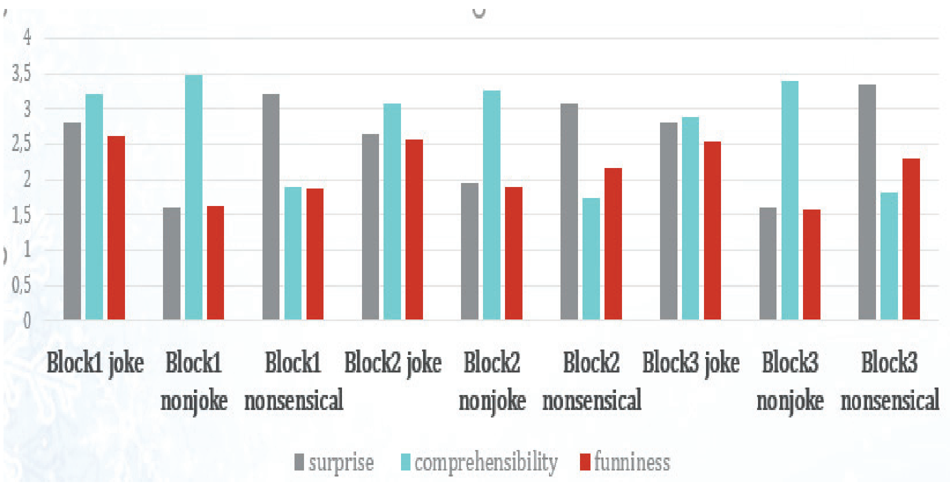


Figure 30 The results of ratings among surprise, comprehensibility and funniness.

5.6.3.2 Correlations between sense of humor and nonjoke comprehensibility / nonsensical surprise

All subjects were required to finish a Chinese-Version Multidimensional Sense of Humor Scale (revised edition) (Wang, 2010) after the experiment, which comprehensively measured the sense of humor from four angles: humor production, attitudes toward humor, coping with humor and humor appreciation. Having a good sense of humor may represent an important coping strategy (Celso et al., 2003). In current experiment, the sense of humor was significantly correlated with the ratings of nonjoke comprehension and nonsensical surprise degree rather than the ratings of the joke funniness like what we had commonly believed (see Table 3 and Fig. 31). Svebak (1974) suggested that individual differences in sense of humor involve variations in three separate dimension: (1) meta-message sensitivity, or the ability to take an irrational, mirthful perspective on situations, seeing the social world as it might be rather than as it is; (2) personal liking of the humorous role; and (3) emotional permissiveness. The first of these dimensions involved a cognitive ability related to intelligence (Ruch, 1998b), which closely related with nonjoke comprehension and the judgement of the nonsensical sentences.

Table 3 The correlations between sense of humor and nonjoke comprehensibility/ nonsensical sentence surprise ratings.

Correlations				
		sense of humor	the rating of comprehension (nonjoke)	the rating of surprise (nonsensical sentences)
sense of humor	Pearson Correlations Significance N	1 8	.908** .002 8	.730* .040 8
the rating of comprehension (nonjoke)	Pearson Correlations Significance N	.908** .002 8	1 8	.738* .037 8
the rating of surprise (nonsensical sentences)	Pearson Correlations Significance N	.730* .040 8	.738* .037 8	1 8

* p<0.05; ** P<0.01

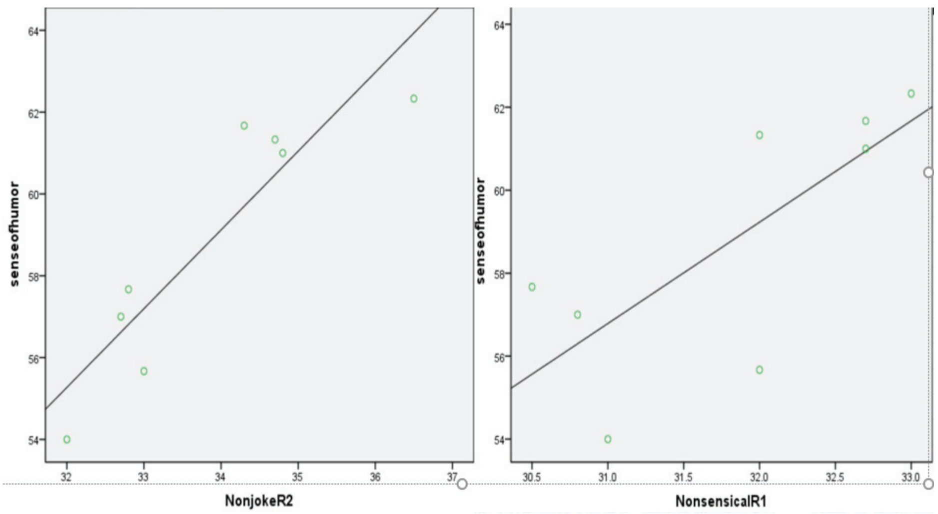


Figure 31 The scatter plot of the correlations between sense of humor and nonjoke comprehensibility/nonsensical sentence surprise ratings (NonjokeR2: the rating of comprehension of nonjoke; NonsensicalR1: the rating of surprise of nonsensical sentences).

5.6.4 ERPs Results

ERPs data was processed and analyzed offline using Metlab 2013. The component amplitudes were analyzed with repeated measure ANOVAs using the factors task conditions (joke, nonjoke and nonsensical sentence) and electrode site (Cz, Fz, Pz). And the .05 level of significance was adopted throughout all analyses. All stimuli elicited P1/N1/P200 and N400 components, which were typical of ERPs to visually presented words. Effects were obvious on the P2 and N400 wave forms. And all jokes elicited P600 (500-700ms) and LPP (800-1500ms) components, which were typical of ERPs to humor appreciation.

5.6.4.1 P200 effect is specific to Chinese verbal jokes

The visual P200 is a positive going electrical potential of the event-related potential measured at the human scalp which peaks at about 200ms varying between about 150ms and 275ms induced by visual input stimuli (Xie, et al., 2016). It is known to us that P200 is triggered by visual stimuli relevant to visual search, attention, language context information and memory. In language processing, P200 could be modulated by the contextual information, such as sentence-level constraints or congruity associated with the target word (Coulson and Brang, 2010). P200's amplitude will also be modulated by many different factors of visual stimuli. In general, the P200 may be a part of cognitive matching system that compares sensory inputs with stored memory (Freunberger et al., 2007). The P200 has been shown to respond to task-relevance (Michalski, 2000) and emotion (Paulmann and Kotz, 2008).

However, Ziegler, Benraiss and Besson (1999) did not find difference in P200 between homophones and non-homophones by using semantic judgement tasks. What's more, P200 was not confirmed to have definite relation between orthographic processing and phonologic processing, decided by western language alphabetic writing system, which has no corresponding meanings in orthographic part and phonologic part. By contrast, Chinese characters, as ideographs, have very distinctive hieroglyphic features. In a number of Chinese language research, P200 was investigated to be regarded as an indicator of early processing of Chinese characters. Xie et al. (2016) drew the conclusion that P200 effect was relevant to both orthographic and phonologic processing simultaneously.

In this experiment, Chinese verbal jokes were selected to be the stimuli, so the unique Chinese non-alphabetic writing system decided that its processing mechanism would be different from alphabetic language verbal jokes. The data revealed that after the stimuli, in 200ms time window, there was a very obvious positive amplitude for all three conditions: jokes, nonjokes and nonsensical sentences, and there was a significant difference among these conditions (see Fig. 32): the one-way analysis of variance was: $P = 0.0419$, $P<0.05$. Nonjoke's amplitude (set up sentence and punch line are congruent) was more positive than jokes (set up sentence and punch line were seemingly incongruent, needing resolution afterwards) and nonsensical sentences (set up sentence and punch line were incongruent, and the incongruities cannot be solved), and there was no significant difference between jokes and nonsensical sentences. These findings were consistent with previous literature materials. Zinchenko's (2015) experiment indicated that there was reduced P200 amplitude to incongruent trials relative to congruent trials, probably reflecting a reduced information gain from incongruent stimuli. Besides, larger P200 amplitudes were observed for expected endings than for unexpected ones in the sentences reading task (Moreno and Rivera, 2013).

The results in this experiment implied that congruent and incongruent information and information regarding Chinese verbal jokes were already integrated in 200ms after stimulus onset (see Fig. 32), which possibly revealed pre-processing of semantic integration of Chinese verbal jokes.

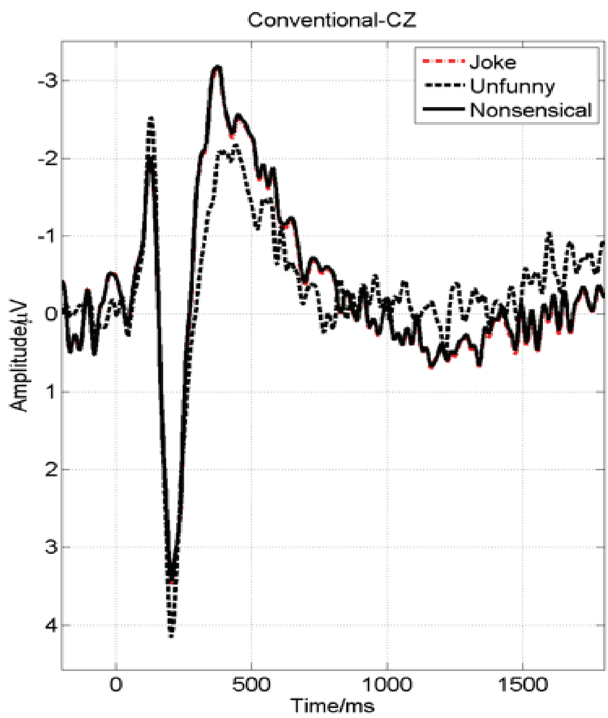


Figure 32 Grand average ERPs at Cz

5.6.4.2 Classic N400 Effect

In this experiment, between 350 and 450ms, all stimuli: jokes, nonjokes and nonsensical sentences, elicited significant negative amplitudes, N400, which was firstly reported by Kutas and Hillyard (1980a) when Participants responded to a semantically anomalous word in a sentence context, wherein more predictable words elicited smaller N400s than less predictable words. What's more, Coulson and Kutas (2001) also showed that the N400 was more negative for jokes than for nonjokes in high-constraint sentences but not in low-constraint sentences. In addition, Du et al. (2013) indicated in their experiment that funny items elicited a more negative ERPs deflection (N350-400) than did unfunny item, which might reflect the registration of surprise in joke comprehension. The N400 effect functionally reflected semantic integration, linguistic, and non-linguistic context, and conceptual binding with the long-term-memory during an active comprehension process (Kutas and Federmeier, 2011).

In this study, the jokes and nonsensical sentences were more surprising than the nonjokes. Therefore, the jokes and nonsensical sentences elicited a more negative ERPs in about 400ms than did nonjokes, reflecting incongruity processing during language comprehension, which indicated semantic integration and an updating of semantic expectations, and there was a significant difference among three conditions in electrode Cz and Pz ($P=0.0013$, $P<0.05$), which were consistent with the hypothesis.

5.6.4.3 Separating P400 from N400 Effect in Processing Chinese Verbal Jokes

Besides using the conventional data analysis method, we combined temporo-spatial principal components analysis (PCA) and item averaging to decompose the wave forms, because a promising tool for separating and characterizing subcomponents (such as the N400 and the P400) was principal components analysis or PCA (Dien and Frishkoff, 2005; Mocks and Verleger, 1991). The application of an optimal filter designed for the desired ERPs source did not change the original topography. Since the optimal filter assisted to achieve a more reliable Independent Component Analysis (ICA) decomposition, the estimation of the topography may become more reliable through ICA too, which was very important to the source localization of ERPs (Delorme and Makeig, 2004; Blankertz et al., 2010).

Moreover, the design of an optimal filter should be based on the prior knowledge on the ERP source of interest, such as the temporal and spectral features (Cong et al., 2010). The proper wavelet based analysis can be one appropriate candidate for optimal filter or another preprocessing method for ICA (Cong et al., 2011). Therefore, in data preprocessing phase, 50Hz grid were removed; 0.5 Hz high-pass filtering was done; 30 Hz low-pass filtering was also done; the baseline was removed; the trials with the peaking more than 100 microvolt were removed and finally, the data were overlaid on average.

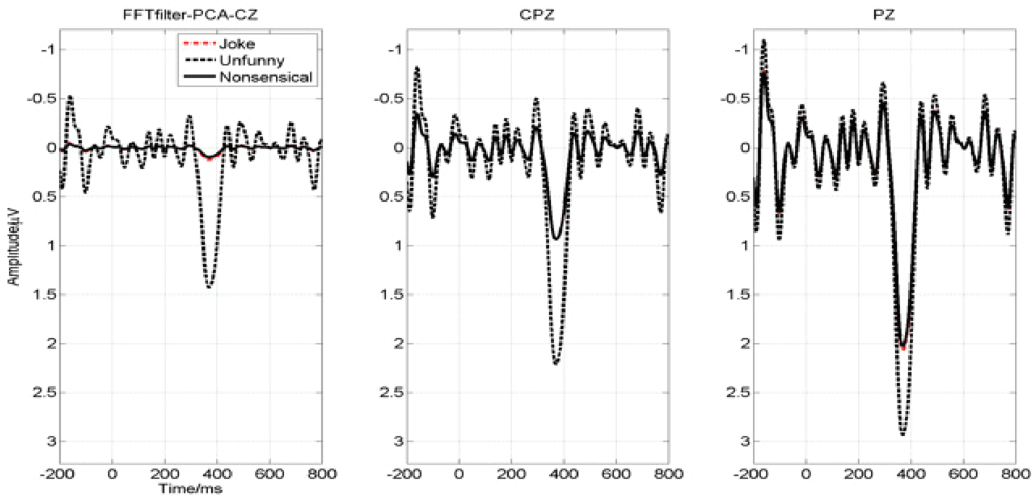


Figure 33 Grand average ERPs at Cz, CPz and Pz by PCA.

The parameters of the FFT settings were: fL= 0.5; fH= 30; fs=512; M=10*fs. The positivity peaking at 400ms was more positive to nonjokes and there were significant differences among three conditions: jokes, nonjokes and nonsensical sentences (see Fig. 33), in three electrodes. For

Cz, $P = 2.25070e0\text{-}004 < 0.05$,

CPz, $P = 9.528e\text{-}06 < 0.005$,

Pz, $P = 7.3884e - 004 < 0.005$.

These results were in line with Dien's (2010) findings: Cz-centered P400 was also responding to semantic congruity manipulations, which was more positive to congruent endings, distinct from the classic N400, which was more negative to incongruent endings. Both classic N400 and P400 contributed to the sentence N400 semantic congruity effect and incongruity detection in humor processing.

5.6.4.4 ERPs Source Analysis

In order to explore the brain mechanism of joke comprehension and the precision of source location, we transformed time domain into frequency domain by Fast Fourier Transform Algorithm (FFT), and then employed spatial Independent Component analysis (ICA) to locate the corresponding brain regions from stimuli onset (see Fig. 34). The reason for that was spatial Fourier-ICA provided a concise summary of the spatiotemporal and spectral content of spontaneous neuromagnetic oscillations in cortical sources space over time scales of minutes, which seemed valuable for inferring functional connectivity, stimulus-related modulation of rhythmic activity, and their commonalities across subjects from non-averaged MEG data (Ramkumar et al., 2012).

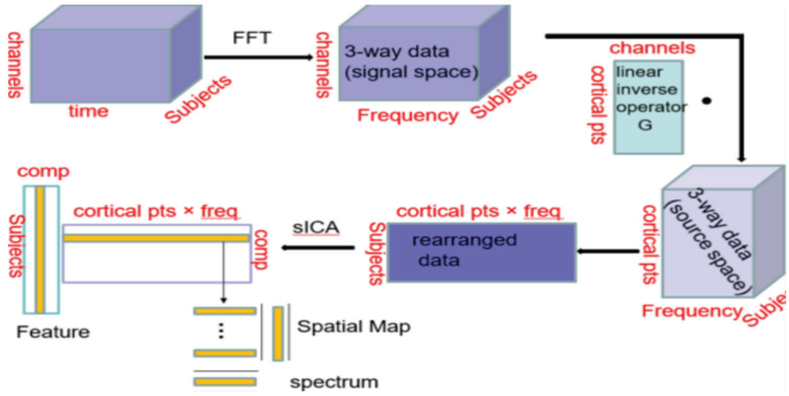


Figure 34 ERPs source analysis algorithm.

In this experiment, three conditions jointly activated frontal lobe, Broca's area, temporal lobe and occipital lobe in both hemispheres. But in right hemisphere, Broca's area was activated much more than in the left hemisphere, and Wernicke's area and insular cortex were also activated and both had very strong activation (see Fig. 35), which suggested that right hemisphere has the last laugh, also indicated by the experiments by Marinkovic et al. (2011). Coulson and Wu (2005) also presented the result that semantic activations in the two hemispheres did differ, with right hemisphere semantic activation facilitating joke comprehension. Insular cortex was believed to play a role in mapping visceral states that were associated with emotional experience, giving rise to conscious feeling (Damasio, 2000). In this experiment, the insular cortex was strongly activated in right hemisphere, which suggested that the stimuli triggered very strong emotions caused by jokes or nonsensical sentences. These results were in accordance with what Gardner et al., (1975) showed: the left hemisphere might be associated with integrating information into a congruent form to understand a joke, whereas the right hemisphere might be responsible for emotional processing (Du et al., 2013).

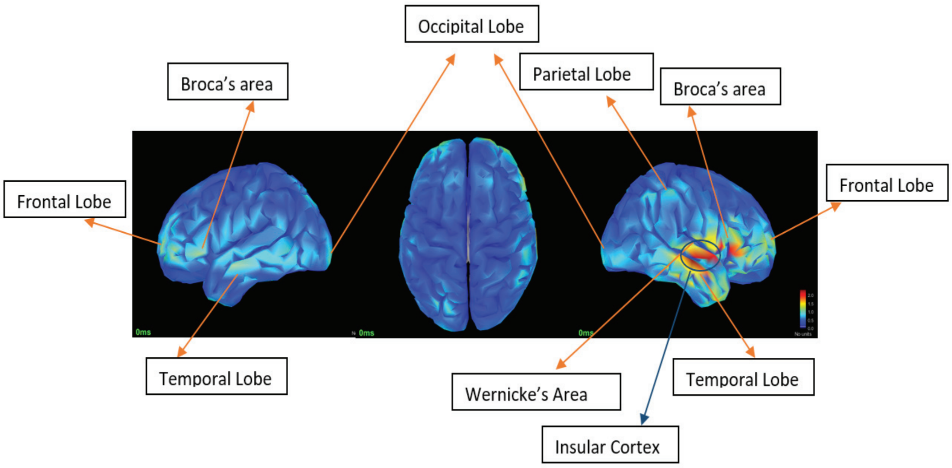


Figure 35 Brain regions elicited after the stimuli onset.

5.6.5 Discussion

In order to avoid the reviewing effects, each participant can read the punchline for only one time, so that 24 participants were divided into eight groups as eight subjects. Inside the group / subject, it was inevitable to have the individual difference though the participants were randomly grouped. In addition, although all jokes had been screened by another group of participants different from the subjects in this experiment beforehand, we cannot neglect the probability of individual differences in joke processing. For the material selection, it was hard to completely eliminate the semantic association for nonsensical sentences, but we tried to keep it low. The current experiment suggested that there were four stages appearing in processing Chinese verbal jokes. The first stage, P200, was peculiar to Chinese verbal jokes. but, P200, as an early component, was easily influenced by N1, P1 and P3, and different tasks would make difference in subjects' attention level, processing depth and expectancy, which would probably change the latency and time window of P200 (Xie et al., 2016). That's what we should further testify in future experiments. In the future research, besides adding more subjects to the experiment to increase the validity of the ERP data, oscillation analysis should also be emphasized to provide more evidence on the processing mechanism of humor, which will be helpful to the relevant technological artifact development.

6 COMPUTATIONAL HUMOR

To explore human cognitive processes by creating computer models that will exhibit "intelligent" behavior, researchers launched the investigations in Artificial Intelligence, constructing the analogy between human mind and the computer (Matlin, 2005). Some emergent newer disciplines integrated Artificial Intelligence with cognitive science to deal in formal and computationally testable models of human behavior, investigating complex phenomena, such as visual perception, physical mobility, language use and reasoning (Ritchie, 2004). One of the newer disciplines was computational humor, using computer to conduct humor research on the basis of Artificial Intelligence and computational linguistics. It is a sub-discipline of computational linguistics with applications in human computer interfaces, edutainment, affective computing, intelligent agents and other areas (Hempelmann et al., 2006).

The computational investigations into humor started in the last decade along with the development of Artificial Intelligence, and in the meantime, the development of computational humor also contributed to a step further forward to the realization of Artificial Intelligence. Artificial Intelligence is the technology with strong sense of times, which has been introduced in a number of different fields, so that it cannot be ignored by researchers for its widely infiltrating and influential impacts on people's way of life. Computational humor can automatically identify humor, generate humor and help further understand the mechanism of humor appreciation from the perspective of cognitive linguistics. It only deals with the humor in speech in natural language context and results in the corresponding symbolic processing model. Other types of humor, such as cartoon, comedy film, slapstick, and stand-up comedy etc. are not under consideration (Ritchie, 2001). Thus, the attention of the following content is confined to verbal jokes, the humor in natural languages.

Verbal jokes are related to the formalization of linguistics in the 20th century, which began in phonology and then extended to syntax and, later, to semantics (Taylor and Raskin, 2012). Jokes and witticisms can exploit the highest structural levels of language, from discourse and genre conventions to narrative forms, down through sentence structures, word-order conventions, agreement constraints, all the way down to morphology, spelling, pronunciation and stress patterns (Attardo, 1994; Ritchie, 2004; Raskin, 2008; Veale et al., 2015). Based on the cognitive linguistics, the Semantic Script Theory of Humor (SSTH) provided machinery with formalizing the structure of most types of verbal humor (Ruch, 1993). Besides, advances in computational humor may be viewed as a rich source of potential hypotheses for further experimental research (Anderson, 2005).

6.1 Humor and cognitive linguistics

If language is the ultimate killer-app of the mind, it can often seem that humor – as a powerful conceptual, communicative and social application – is the killer-app of the language, in the deepest and most subversive sense of "killer" (Feyaerts and Oben, 2014). Cognitive linguistics covers a variety of natural languages, so the wide-ranging cognitive linguistics is much needed for the study of humorous language (Veale et al., 2015), building up for the computational humor as well. From the perspective of cognitive linguistics, language can leverage many diverse aspects of cognitive process to explore, shape and communicate our feelings, beliefs and ideas (Veale et al., 2015). Humorous language in particular employs the conflicts to reveal the implicating meanings of surface language delicately, effectively and impressively, helping people to convey specific feelings. There are very clear clues to trace the similarities of linguistics and humor research, with the drive within Chomskyan linguistics to evolve a universal theory of language, or at least of grammar (see Table 4): in generative grammar, strings of words are seen as the basic data to differ from grammatical strings, while in humor research, grammatical texts are regarded as the basic data to distinguish jokes from nonjokes; 'description of a joke' and 'definition for a joke' are just the syntax aspect embodied in sentence structure and grammar rules in linguistics; 'theory of grammar' is to build up the 'theory of language' and 'theory of jokes' are to become part of, or inform the work on, a theory of humor (Ritchie, 2004).

Table 4 An analogy between linguistics and humor research (Ritchie, 2004)

Linguistics	*Humour research*
Strings	Grammatical texts
Grammaticality	Being a joke
Sentence type	Subclass of jokes
Structural description	Description of a joke
Grammar rule(s)	Definition for a joke class
Theory of grammar	Theory of jokes
Theory of language	Theory of humour

6.1.1 Construction grammar and humor

Construction grammar is a particular linguistics school, deriving from the field of cognitive linguistics in 1980s, can be applied to almost all linguistic research. Construction itself signifies to combine different parts together to form a bigger thing, which is vividly used in the terminology of construction grammar to illuminate the significance of integrating all linguistic knowledge to form the network of language. The origin of construction grammar can be traced back to the grammatical theories in the old Greece. At that time, scholars proposed that language was the mind, the symbol response to the psychological process, which showed that language was the one-to-one correspondence between formation and meanings. Even if we can fully understand all the lexicons, we probably cannot understand the formations and the meanings of a text, since every sentence and every discourse contain its own particularly important features which are the key to the comprehension.

In construction grammar, the range of the construction seems like very broad, which covers the morphemes, words, idioms and sentence, then extending into the discourse. A very principal idea in construction grammar is that grammar is generative rather than transformative, and the grammar formation is just the construction of the language, not an epiphenomenon of grammatical transformation, as the construction of grammar is closely related to the human empirical experiences. Construction grammar may therefore provide cognitive grounding and a rigorous methodology to the analysis of large-scale patterns by recognizing that, just like sentence-level constructions, they also consist of less and more fixed parts, of semantic and lexical material (Antonopoulou et al., 2015).

Construction grammar supports an integrated approach to humor language analysis, in which information, about the lexicon, sentence, discourse and text, registers features complying with a form, represented in the meaning pole of the corresponding construction (Antonopoulou et al., 2015). That is to say, construction grammar focuses not only on lexicon level, but also on sentence level and discourse level as well, even text level, all of which cohere and then generate the humorous incongruity and resolution in a humorous context. Lexical structures serve to modify the sentence meaning, discourse meaning even text meaning by reaching the coherent level to test whether the discourse prediction is true, which is essential to analyzing humorous language.

6.1.2 Embodied grammar and humor

For centuries, most humor research mainly focalized in the humor comprehension and appreciation, and these studies seldom involve the perspective of linguistic structure. In 1957, Chomsky (1957) published his "Syntactic Structures" and proposed his transformational grammar, which laid the foundation of cognitive science and at the same time, started the research in cognitive linguistics. Cognitive linguistics is experiencing a great change in these twenty years because of the great influence from the research of artificial intelligence and robotics study. In the course of the great changes, embodiment, a new orientation in cognitive science, is also markedly impacting cognitive linguistics. Relating with humor research, the applicability of cognitive linguistic to humor derives from its emphasis on the embodiment of language - how it is used by humans with particular sorts of brains and bodies, with particular physical and social goals in specific physical and social contexts (Chrisley and Ziemke 2002; Bergen and Binsted, 2015).

Embodied theories of language stressed language as an embodied cognitive system, which was mainly about specific cognitive process involved in language understanding, production, its relevant social aspect, mental simulation and the language user's imagination. Furthermore, embodied theories of language focused on how language was actually used, which was not only about the cognitive process but also about a combination relevant to the cognitive process, such as the language user's cognitive ability, creativity, his or her own experience and social context. Similarly, humorous utterances used existing linguistic structures, either recruiting their pragmatics, or, when conventionalized as being used for humor, having a humor-specific pragmatics cued by context and depending on subtleties of interpretation relating to imagery (Bergen and Binsted, 2015) and language creativity.

Grammatical knowledge is very closely related with both humor understanding and humor production. For example, the familiar knock-knock joke had its own fixed grammatical formations, which were specified in syntactic, lexical and sometimes phonological terms (Bergen and Binsted, 2015). Grammar itself cannot be humorous, but when combining additional mechanisms with embodied cognition, the humorous effect may be activated. In short, humor relates to both linguistic form and embodied grammar involved in cognitive processes against certain social interactions.

6.1.3 Metaphor and humor

The most prominent tenant of a conceptual or cognitive similarity between metaphor and humor is the notion of conceptual duality (Müller, 2015). Duality embedded itself in metaphor as the conflicts between two ideas in two domains: source domain and target domain. Duality is also significant for humor theoretically, since it is the foundation of the incongruity rooting in the comprehension between two contradictory or seemingly unrelated concepts or cognition. Thus, duality runs through the whole process of both metaphor and humor.

Arthur Koestler (1964) indicated the same conceptual mechanisms shared by metaphor and humor by putting forward to the idea of bisociation: the perceiving of a situation or idea in two self-consistent but habitually incompatible frames of reference, which is the base of metaphor, humor and scientific invention. Although metaphor and humor are not the same thing for their different cognitive mechanisms, both of them have metaphorical analogy. Usually, after the comprehension of jokes, laughter is left to people, while after the comprehension of the metaphor, insight is left to people. Furthermore, the crucial aspect of humor appreciation is to keep the conflicts between two ideas, but the most important factor of metaphor is to combine two different ideas together to produce a creative and deep understanding, or insight into something.

6.1.4 The linguistics analysis of verbal humor

The linguistic theories of humor, whose components can be roughly defined by adding 'verbal' or 'textual' before each occurrence of 'humor', has finally reached a level of formal representation that is adaptable for the computation for any humorous text (Raskin et al, 2009; Taylor, 2011; Hempelmann and Attardo, 2011; Taylor and Raskin, 2012). Verbal humor has also been referred to as verbalized humor: jokes are expressed by means of a linguistic system (Attardo, 1994). One methodological issue in studying verbal humor is the need for linguistic notions such as 'word', 'sentence', 'type of speech act', etc., and linguistics here will be taken in a fairly broad sense, to include pragmatics as well as morphology, syntax, semantics, phonology etc. (Ritchie, 2004). However, differing from common-sense conventional linguistic analysis of the text, verbal jokes have more flexible divisions in its humor linguistic analysis. For example, for some homonym jokes, it is very difficult to decide the divisions from the perspective of linguistics, since there is no morpheme element in the similar pronunciations among the homonyms which finally arouse the humorous effects. It seems that there will not be a single well-defined level of grouping of phonetic units into slightly larger units relevant to humorous constructions and joke-making has complete freedom to group and segment without regard to any particular set of linguistics classifications (Ritchie, 2004). Thus, besides conventional linguistic analysis to verbal humor, verbal humor should also include some specific analysis which has communicative differences, like phonetic or orthographic units.

Incongruity is the essence of humor, and this assertion first appeared in 1759, referred by Keith-Spiegel (1972). Afterwards, many researchers focused on the incongruity to further explore their relevant research: Morreall (1987) elaborated his philosophical ideas in humor research by incongruity; Shultz dissected humor phenomenon in psychology by incongruity; and Raskin and Attardo formed linguistic theory of humor by incongruity. The Incongruity Theory in literature presented itself in different forms or expressions, for example, bisociation, proposed by Koestler (1976), which embodied the appropriate notion of incongruity. Raskin's (1985) Semantic Script-based Theory of Humor (SSTH), the most prominent bisociation theory in recent decades, is one of the few which even starts to address the notion of 'frame' to elaborate on which kinds of frame-clash (script opposition) are humorous (Ritchie, 2004).

Based on SSTH, the General Theory of Verbal Humor (GTVH) (Attardo and Raskin, 1991) is widely accepted across the various disciplines involved in humor research as a theoretical basis for relevant studies. The detailed content of GTVH has been introduced in the previous content in Theoretical Bases. On balance, GTVH has gained, despite its faults and lacks, a canonical status such that it is nearly impossible to find published humor research that does not make reference to it in some way (Rutter, 1997). Nevertheless, these two theories also received a number of arguments. Ritchie (2004) summarized some queries in the definition of the basic concepts in GTVH, such as scripts, script opposition, and their logical mechanisms. There is no central framework in GTVH parameters; some of the knowledge resources listed seem to describe general textural characteristics rather than humorous ones; the SI parameter is indeed applicable to general texts (Attardo et al., 2001), not just humorous ones, but it also seems plausible that any text could be classified according to its language and narrative strategy, and a non-humorous text might even have an intended target.

6.2 Computational humor models

Though there are a great number of humor researches being investigated from different perspectives, the complexities of the use, comprehension and appreciation of humor still need further illumination. How actually humor works and how to simulate humor computationally are still unresolved. Some existing practical artifacts of computational humor have provided researchers with valued reference to the solutions incorporating with Human Computer Interfaces (HCI). Here, we have to confine the computational humor research to verbal humor, since covering different types of humor is too ambitious to realize at the moment. It would be very easy for a would-be general theory to fail either in its generality (i.e. not cover all the possibilities) or in its accuracy (i.e. cover some data incorrectly) or even being a theory (being so vague as to not make any meaningful predictions that could be falsified) (Ritchie, 2004).

Computer programs base the research on language processing mechanisms to simulate the humorous effects. There are two obvious ways of implementing the workable models of humor: as a humor generator and / or as a humor understander (Ritchie, 2001). Humor generators can be mainly applied to HCI to entertain people and make the interpersonal interactions more acceptable, and at the same time, they can also be used in specific fields to help increase the work efficacy and learning efficacy. For example, in education, simple jokes for children can stimulate the study interests to explore more about the knowledge. The humor understander will contribute to the development of artificial intelligence by identifying the structures of jokes to allow future robotics understand jokes and react alike.

6.2.1 Knock-Knock joke recognizer and generator

Based on Raskin's SSTH, considering that the essence of most jokes is the wordplay, similar pronunciations and incongruous meanings between two scripts, the Knock Knock (KK) recognizer was developed by employing N-gram, a most broadly useful practical tool in language processing. An N-gram is a model that uses conditional probability to predict Nth word based on N1 previous words. N-gram can be used to store sequences of words for a joke recognizer, typically constructed from statistics obtained from a large corpus of text suing the co-occurrences of words in the corpus to determine word sequence probabilities (Taylor et al., 2004). The most important part of the process of joke recognition or joke generation is the model can build up similar-pronunciation words or expressions to replace the key word in the Knock Knock joke, so this model mainly depends on selecting letter-pairs of similarity table. If the joke format validation is finished, the model generates the similar-pronunciation replacements. Then, the bigram (Ngram, N=2) table will be used for validation and the wordplays that make sense will step into the step of last sentence validation. If the replacement is not successful to make sense or function as the punchline, two trigram (Ngram, N=3) sequence will be used to start over. The steps of the joke recognition process are (Taylor et al., 2004)

Step 1. Joke format validation
Step 2. Generation of wordplay sequences
Step 3. Wordplay sequence validation
Step 4. Last sentence validation

6.2.2 Ontological Semantic Technology

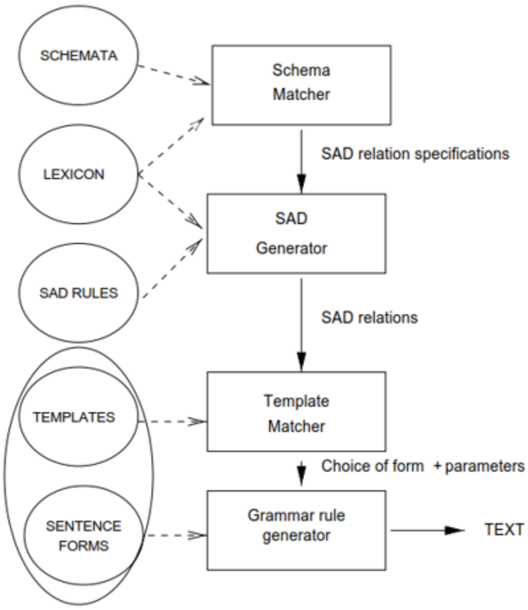
This model discusses the computational linguistic/semantic preconditions for computational humor and an ontological semantic approach to the task of humor detection, based on direct and comprehensive access to meaning rather than on trying to guess it with statistical-cum-syntactical keyword methods (Taylor, 2010). At the core of Ontological Semantic Technology, there are repositories of world and linguistic knowledge, acquired semi-automatically within the approach and used to disambiguate the different meanings of words and sentences to represent them comprehensively (Taylor and Raskin, 2012). The semantic analyzer, software that outputs text meaning representations, is used to analyze each lexicon, containing word senses rooted in the ontology. And the ontology, with the characteristics of natural language: vagueness and fuzziness, consists of language-dependent concepts and relationships between them. The ontology is governed by specific rules for any concepts and relationships against humorous background (Taylor and Raskin, 2010).

6.2.3 JAPE (Joke Analysis and Production Engine)

JAPE's joke analysis and production engine is merely a punning riddle generator. It is not based on a theory that would provide a basis for the meaning generation in the mathematical sense intended by Chomsky (1965), but it provides a good example of a limited-range application based largely on ad-hoc decision during its creation (Hempelmann et al., 2006). For example, “What is the difference between a pretty glove and a silent cat?” “One is a cute mitten, the other is a mute kitten.” In this punning riddle, there is a kind of special networks of constraints between words and parts of words (part of the pronunciation of the word). JAPE system employed a very simplified model of language processing: the text strings are orthographic rather than phonetic forms, but the internal computations by the rules make explicit use of both orthographic and phonetic representations as well as lexical entries; the syntactic categories are labeled such as ‘noun’, ‘verb’, etc.; to distinguish between separate lexemes with the same string and syntactic category, sense is done to be a unique identity marker, which allows individual senses with the same syntax and surface from to enter into different lexical relationships (Ritchie, 2003). The JAPE procedure is to search the dictionary for words and phrases which satisfy this schema, thereby instantiating the schema (Ritchie, 2004) and its rules are mainly based on schemata, sentence forms, templates and SAD (Small Adequate Description) (see Fig. 36 for more details).

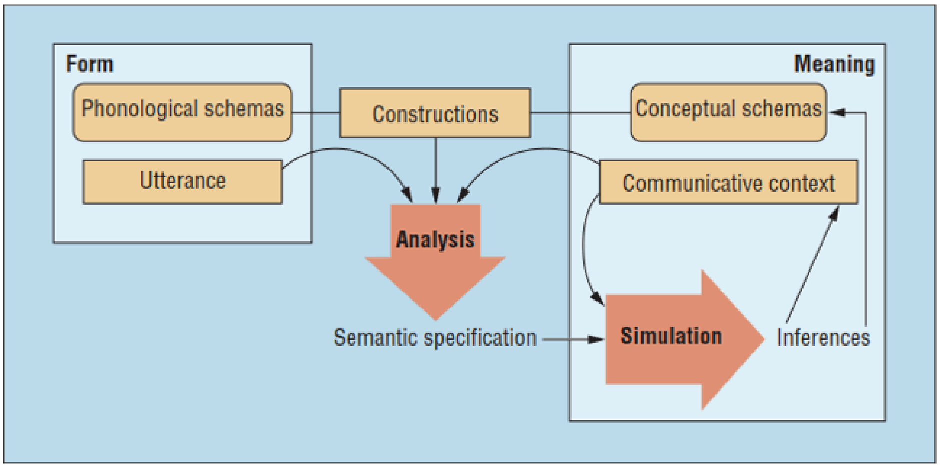
6.2.4 Simulation-based natural language-understanding system

This system was developed on the basis of Embodied Construction Grammar, which has two pain processes: analysis and simulation (see Fig. 37). At the first step, the system reads in each new word (transformed from the spoken words) and combines them into competing sets of lexical and grammatical constructions. Then, the system analyses the semantic meanings of each network of construction. Once the threshold, defined by the parameterized schematic representations which activate the stimulation device, is beyond certain values, the system will include the semantic specification into the simulation engine. Subsequently, the simulation engine begins to run the correspondingly appropriate schema with the programmed parameterizations. In the next step, the system will decide whether there is a semantic incoherency between the set up and the end of the narration by referencing the highest-level construction in the sentence, the “X is so Y that Z” construction. What’s more, the simulation produces appropriate affective and encyclopedic inferences so that it can update its knowledge about the world. The advantage of this system is to identify the semantic incoherency, which is the essence of humor appreciation and creation, using the real-world knowledge to capture subtle semantic differences in the meanings of particular words that arise in the simulation and not in the semantic specification (Bergen and Coulson, 2006).



JAPE's rules basically cover four different types: schemata, sentence forms, templates and SAD (small adequate description) generation rules. A schema contains both lexical preconditions and output specification, describing a configuration of lexemes which would form the central underlying structure of a riddle and indicating which of these lexemes are to be used in the surface form. SAD generator acts on the information supplied by a schema, fleshing out the lexemes, which are more detailed description of linguistic structures. The information passed to the SAD generator from the schema processing indicates not only what lexemes are to be used to create constituents, but also what the relations are to be between these constituents once created. The JAPE system made use of one of such relations to describe the same concept. These equation-like structures are passed to the template stage. A template contains some conditions describing the internal structure of the SAD relations it receives and a computation to extract information from the items with SAD relations (Ritchie, 2003).

Figure 36 An overview of JAPE (Ritchie, 2003)



- The analysis process determines which constructions the utterance instantiates. The main product of analysis is the semantic specification, which specifies the conceptual schemas evoked by the constructions involved and how they are related.
- The simulation process takes the semantic specification as input and exploits representations underlying action and perception to stimulate the specified events, actions, objects, relations, and states. The inferences resulting from simulation shape subsequent processing and proved the basis for the language user's response.

Figure 37 Overview of the simulation-based language comprehension model, consisting of two primary processes: analysis and simulation. Construction plays a central role in this framework as the bridge between phonological and conceptual knowledge (Bergen and Chang, 2005).

6.2.5 Automatic Humor Recognition

In computational humor, humor recognition is significantly important. A subtle and effective recognition system plays a key role in investigations into computational humor. In an experiment, the one-liners with simple syntax and creative rhetoric features were targeted to probe the applicability of the following system. Firstly, to build humorous data and non-humorous data, web-based bootstrapping algorithm was used to collect one-liners (see Fig. 38). This system mainly combined humor-specific stylistic features and content-based features together to realize the automatic humor recognition. In detail, by identifying alliteration/rhyme chains, the system extracted the alliteration features and then, based on WordNet, the antonym was identified among the words from different part of speech. Further, the adult slangs were also considered due to its popularity in humor resources. Secondly, some frequently used text classifiers were employed to estimate the probability of a category given that a document used joint probabilities of words and documents, for example, Naïve Bayes. Good performance can finally be achieved by using classification techniques based on stylistic and content features (Mihalcea et al., 2005).

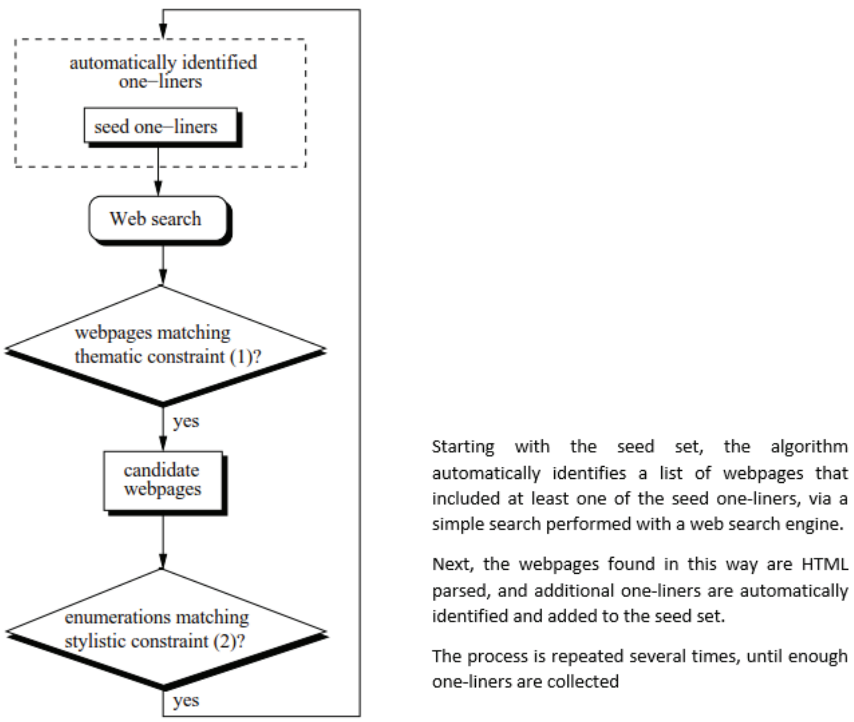


Figure 38 Web-based bootstrapping of one-liners (Mihalcea et al., 2005)

6.2.6 Computational incongruity detection model

As mentioned before, the incongruity detection is the key to humor appreciation and creation, and this model is just built up for the accurate identification of incongruity in humor. The model was constructed on the basis of a data set, which consists of 150 set-ups and each set-up was followed by four different continuations, including one funny continuation (punch line). The set-ups and their corresponding continuations derived from 150 one-liners, containing simple but funny effects.

The process analysis focused on two specific sub-models: one was to detect semantic relatedness, including knowledge-based metrics, corpus-based metrics and domain fitness; the other was to detect the joke-specific features, including polysemy and latent semantic analysis trained on joke data. The word-to-word relatedness was measured by a metric that combined with the semantic relatedness. For example, the first word of the set-up would be first related to every word in the set-up, and then related to every word in the punchline; after that, the second word started the same procedure over from the beginning and then the same with the third word till the ending word of the one-liner. The comparisons among the words would then be summed up and the final relatedness scores would be presented by using a simple average on the basis of the WordNet hierarchy.

In addition, the semantic relatedness can also be measured by using information coming from large corpora considering both pointwise mutual information and latent semantic analysis. The semantic domains also helped to identify the semantic relatedness in many fields, such as education, art, and politics. Specifically speaking, the usage domain of each word was measured, and then the latent semantic analysis stemming from the British National Corpus was considered. The pseudo document representations of the domains from the set-up and the continuations were built up and finally the domain similarities among the set-up and the punchlines were measured by using a cosine similarity applied on the pseudo document representations (Mihalcea et al., 2010). Additionally, the mean Polysemy will be checked and the number of alliteration or rhyme chains will also be counted.

6.2.7 Script model + Concept clustering (SM+CC)

This computational humor model instantiated the SSTH at the fundamental level, without imposing constraints on phonological similarity, or a restricted set of domain oppositions (Labutov and Lipson, 2012). It consists of three stages: script model, ranked scripts and surface form. In detail, the first stage started from the root concept by examining all paths for feasible script pairs, including time, location, events and results, and then radiated to maximize the outgoing edges to search semantic overlaps. After that, when the activation weight was below a certain threshold, the scripts would be scored by ranking the activation weight to capture the inter-script, including overlap and incongruity. And finally the surface form or the template would be generated by relating a script pair and a concept, deriving from the selection between different clusters in the entire ConceptNet. In general, this model highlighted the advantage that both script opposition and incongruity were favored through spreading activation and concept clustering (Labutov and Lipson, 2012).

6.2.8 A computational model of humor in puns

Different from the models focusing on joke-specific features or surface linguistic features, the computational model of humor in puns stressed the model of sentence comprehension to elaborate on the incongruous interpretation in humor. This model mainly identifies two quantities in a sentence: ambiguity and distinctiveness, which contained the incongruity between one set of words and the other set of words. Formally, a phonetically ambiguous sentence was composed of a vector of words *w*, "where *h* was phonetically confusable with its homophone *h'*; the sentence meaning was a latent variable *m*, which we assumed had two possible values m_a and m_b; these two sentence meanings can be identified with the homophones *h* and *h'* respectively;" then, the system constructed a simple probabilistic generative model that captured the relationship between the meaning of a sentence and the words that composed it (Kao et al., 2016) (see Fig. 39). The ambiguity was quantified by the entropy of the distribution, and if the entropy was high, then the sentence was ambiguous because both meanings were near-equally likely. Distinctiveness captured the degree to which the semantically relevant words differed given different sentence meanings (Kao et al., 2016). And then by identifying the specific features of a pun, the system predicted human's judgement of funniness and helped explain the essential features of the complex phenomenon of linguistic humor (Kao et al., 2013). After the experiment, the ambiguity and the distinctiveness calculated by this model were both significantly higher for pun sentences than non-pun sentences, which indicated the effectiveness of this mode in understanding linguistic humor in puns.

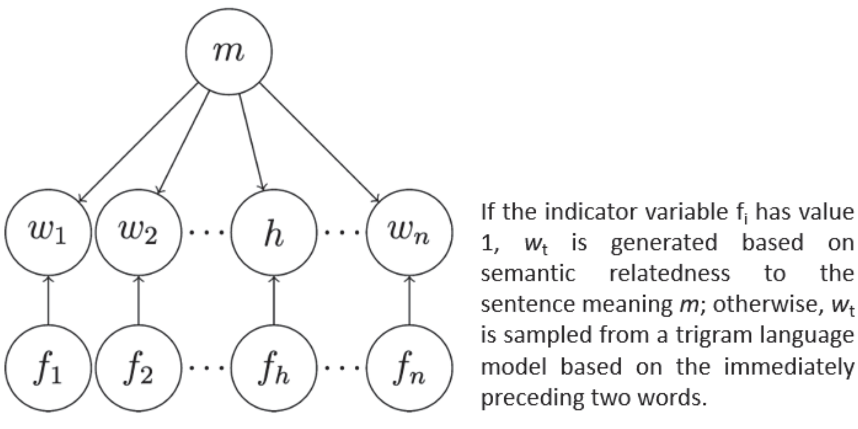


Figure 39 Graphic representation of a generative model of a sentence (Kao et al., 2016).

To sum up, humor studies bear very multi-disciplinary features, with contributions from different research fields, such as philosophy, psychology, linguistics, sociology and literature, but with relatively few from computational field, which is regrettable, for the techniques and methodology of artificial intelligence are well-suited to developing detailed, symbolic and testable models of something as intricate and multi-facetted as humor (Ritchie, 2001). Computational humor, as a branch of Artificial Intelligence, is based on the cognitive linguistics to recognize and generate humorous language through computational models. The above-mentioned computational models are mainly set up on the foundation of corpus and incongruity theory by decomposing the types of knowledge in jokes and many of them are effective in either using joke generators or joke understanders, making it possible to achieve the computerized communication in a humorous way. The development in computational humor research is facilitating the advancement of Artificial Intelligence, which also drives the improvement in Human Technology Interaction (HTI).

In the subsequently proposed emotion design concept employing humor intervention to regulate negative mood, computational models will play an important part in recognizing humorous language and providing artifact users with humorous stimuli. Different types of computational models with specific advantages will be built in the future technical artifact to imitate real interpersonal communications contexts in humorous way via human computer / mobile phone interactions. The integration of computational humor into HTI makes the technical artifacts more humanized.

7 HUMOR AND HEALTH

7.1 Humor and physical health

Humor and laughter is the sweetest medicine for both mind and body, benefiting people on physical health, mental health and social interactions as well. Humor in medicine is an old prescription, show many historical documentations. For example, in ancient Greek, physicians started to use the way of visiting the comedians as one of the therapies to release the symptoms of patients (Kleisiaris, 2014). The proverb from the 10th century, "A cheerful heart is good medicine, but a crushed spirit dries up the bones," and the sentence from the Bible "a merry heart doeth good like a medicine" both addressed significant correlations between positive emotions and health. The positive humor styles often bring people positive emotions, endowing humor with specific medical effects in a way. Since medieval times, physicians and philosophers have indicated that laughter has significant influences on health, such as "improving blood circulation, restoring energy, counteracting depression and enhancing the functioning of various organs of the body (Martin, 2008)." In the 14th century, a French surgeon employed humor as a measure to divert patients from the pain during the treatment and also a way of therapy to help patients recover (Clarke, 1931).

In the last century, the research of humor and health became more and more popular due to the publication of Norman Cousins's (1976) article "Anatomy of an Illness". In 1960s, Noman Cousins was diagnosed with ankylosing spondylitis, a very serious disease causing severe pain. He firmly believed that the positive emotions caused by humor should be closely related with the recovery of the physical functions. Resorting to humorous movies and television shows and an intravenous dose of vitamin C, he saved his own life and lived for another 25 years. Cousin's remarkable attempt by using humor treatment was paid great attention, which helped launch a great number of researches on humor and health. Many subsequent studies also suggested that exposure to humor had positive physiological effects (Berk et al., 1989; Lefcourt et al., 1990; Berk and Tan, 2009; Cann et al., 2010).

Mirth caused by humor is associated with a variety of biochemical processes in the brain and other parts of the body, including changes in the levels of various neurotransmitters, cytokines, opioids and hormones (Ruch, 1993). Those emotion-related biochemical changes may have beneficial effects on physical health by improving pain tolerance, immunity and cardiovascular consequences caused by negative emotions (Martin, 2008). Humor and laughter have also been said to provide some prevention and protections against "cancer, heart attacks, stroke, diabetes, pneumonia, bronchitis, hypertension, migraine headaches, arthritis pain, ulcers and all sorts of infectious diseases ranging from the common cold to AIDS (Martin, 2008)."

Physical health contains many factors and different components of humor could conceivably affect different factors of health in various ways so that five potential mechanisms are considered, each involving different aspects of humor and each suggesting different implications for health care interventions (Martin, 2001). First of all, laughter caused by humor induces many physical activities. Laughter drives the systematic coordinated bodily movement involving rapid deep inspiration, the forcible jerky expiration, the utterance of inarticulate sounds, the facial distortion and the shaking of the sides, and it is demonstrated that various muscle groups are activated for periods of seconds at a time during laughter, with the subsequent general muscle relaxation lasting up to 45 minutes (Paskind, 1932). The respiratory value of humor and laughter involves a disruption of the normal cyclic breathing pattern, increased ventilation, and accelerated exchange of residual air, thereby enhancing blood oxygen levels (Shammi, 2000).

William F. Fry, an emeritus professor of the Stanford University Medical School, was a pioneering investigator who pursued laughter and healing as a field of study and created the term, gelotology (or humor physiology, the science of laughter, examining the most basic issues of human physiological functioning), for the study of laughter (Butler, 2014). Fry (1986, 1992) reviewed humor physiology and concluded that humor and mirthful responses have many positive and beneficial effects for physical health. He stressed that laughter provides exercise for the muscles and heart, produces muscle relaxation, improves blood circulation, reduces the production of stress-related hormones, including catecholamines and cortisol, enhances a wide range of immune system variables, reduces pain by stimulating the production of endorphins, reduces blood pressure, enhances respiration, regulates blood sugar levels, and removes carbon dioxide and water vapor from lungs (Fry, 1994). Fry's pioneering work provided solid evidence and mechanistic insights for the positive physiological impact of humor, which paved the path for the future investigation (Savage et al., 2017).

The general muscle relaxation after laughter was testified by studies (Overeem et al., 2004), which revealed that true laughter evoked more Hoffmann reflex depression than simulated laughter although both laughter and simulated laughter decreased spinal moto excitability, suggesting that mirth on its own can depress the Hoffman reflex and lead to the after-laughter muscle relaxation response. In addition, a total of 599 separate mirth responses accompanied by laughter were recorded and the analysis of respiration wave form indicated that mirthful laughter consisted of varying combinations of expiration, inspiration, and interval pause (Fry, 1977), demonstrating that laughter causes episodes of sharply sporadic deep breathing (Bennett and Lengacher, 2008).

Vigorous laughter is a form of aerobic exercise, causing muscular activity, burning calories, enabling the lungs to expel stale residual air containing built-up carbon dioxide and water vapor, thereby potentially reducing the risk of bronchial bacterial infections (Fry, 1994). As a matter of fact, laughter may have similar physical effects without humor, like forced laugh (Martin, 2010), but forced laughter cannot activate authentic emotional responses like humor, which is critical in bringing positive emotional effects on people. Additionally, humor is the main source of laughter, which reinforces the role of humor in the relationships between laughter and health.

A second mechanism is based on the correlations between the positive emotion and physical health. Positive emotion, like mirth, along with the laughter, emerges after the humor appreciation. This pleasurable emotion is regulated by the limbic system in the brain, which produces changes in the autonomic nervous system and endocrine system that extend throughout the body (Martin, 2010). At the same time, positive emotion also increases heart rate resulting from sympathetic arousal, which promotes cardiac function, produces endorphins and opiates, increases tolerance for pain, being beneficial for the immune system as well (Fry, 1994).

Thirdly, as mentioned before, the core of humor appreciation is to identify the incongruence between the expectations and the real endings, which helps people to break the old mindset by establishing new ways to solving the problem or by viewing the existing problems from new angles. Therefore, different processing mechanism that humor bears helps people employ different outlooks when facing stress and adversity, which makes humor become an effective way of coping with stress, reducing its negative effects on physical health as well as moods (Martin, 2010).

The fourth mechanism is on the basis of the benefits brought about by the improving of interpersonal relationships. As mentioned in previous content, humor itself derives from social interactions, bearing very strong social attributes, and in turn, humor also plays a very significant and effective role in interpersonal relationships, helping the communications go smoothly and helping people win their confidence. Meanwhile, humor enhances positive feelings, which eases the tense atmosphere in communication and increases the satisfying feelings of social relationships, thus, contributing to both physical and mental health.

The fifth mechanism is about the by-product caused by the appreciation of humor, for example, optimistic outlook on life, which contributes to the formation of the regular way of life and the elimination of some bad habits. However, in some cases, humor is also correlated with unhealthy lifestyle. A study (Kerkkänen et al., 2004) showed that higher scores on some sense of humor scales were correlated with greater obesity, increased smoking and factors associated with greater risk of cardiovascular disease.

There is a very popular belief about the positive relationships between sense of humor and physical health, because sense of humor is viewed as an important personality trait which benefits many aspects of physical health. Thus, researchers employed a variety of self-reportings on sense of humor to examine the connections between them, but the results of these studies have been weak and inconsistent (Martin and Lefcourt, 2004). One well-known longitudinal study (Martin et al., 2002) indicated that individuals who had higher ratings of sense of humor and optimism in childhood had a higher risk of living a shorter life. Another study (Kerkkänen et al., 2004) collected the data from 34 Finnish police officers across three years to investigate the relationships between sense of humor and physical health, which revealed that individuals with a greater sense of humor may actually engage in less healthy lifestyle behaviors, such as smoking and overeating. Consequently, more optimistic view on living state may lead to the neglects of some potential problems, causing great problems in physical health.

However, Kuiper and Nicholl (2004) proposed that actually a greater sense of humor may contribute to more positive perceptions of physical health than may be warranted by differing between actual and perceived physical health, which brings people more satisfaction with their health conditions. A research (Diener and Chan, 2011) combined experimental research with naturalistic studies of changes of subjective satisfaction and physiological processes over time and indicated that the high satisfaction causes better health and longevity. Although, this perspective is in fact more involved in mental health, it is also truly related with physical health in some ways. To objectively elaborate the relationships between humor and physical health, greater research efforts, more careful theoretical formulations and more sophisticated and rigorous methodological approaches are needed (Martin and Lefcourt, 2004).

7.1.1 Humor and cardiovascular system

Laughter can activate the changes in cardio-respiratory system: mirthful laughter is accompanied by the increases in arterial blood pressure, followed by pressure decreases below resting pressure levels (Fry, 1988). A study (Clark, 2001) assessed the effects of either anger or laughter on people's physical health, with the results showing that coronary-heart-disease participants were significantly less likely to experience laughter during daily activities, surprise situations or social interactions, which implied that more laugh in daily life may contribute to cardioprotection. Another study (Lackner et al., 2013) examined the transient cardiovascular response to the perception of humor based on two-stage model of humor processing by using humorous and non-humorous cartoons and suggested that the detection of the punch line was followed by a slight increase in heart rate with the increase cardiac output (Lackner et al., 2013). As a result, mirthful laughter serves as a useful and important vehicle for the promotion of vascular health. In addition, "mirthful laughter induces the release of β-endorphins which has high affinity for μ3 opiate receptors upregulating nitric oxide synthase to enhance production of nitric oxide, exerting a variety of cardioprotective cellular functions via cellular signaling pathways, including a cGMP-dependent pathway responsible for vasodilation to reduce platelet aggregation as well as inhibition of leukocyte trafficking for reduction of vascular inflammation (Miller and Fry, 2009)." Besides, mirthful laughter, as a preventive adjunct therapy in diabetes care, raises high density lipoprotein cholesterol levels and lowers inflammatory cytokines, and high sensitivity C reactive protein levels, with these modulation effects' lowering cardiovascular disease risk and fewer myocardial infarction reoccurrence (Berk and Tan, 2009).

7.1.2 Humor and neuroendocrine system

To detect changes in neuroendocrine hormones during a mirthful laughter experience, a study was conducted with 10 healthy male subjects viewing a humor video, compared with 5 control subjects, who did not watch humor video. The results indicated that, in the whole process of video-watching, epinephrine levels in the humor-video-watching subjects were significantly lower than the control subjects; the growth hormone levels also significantly increased during baseline and then decreased with laughter intervention for humor-video-watching subjects, whereas the controls did not change over time (Berk et al., 1989). Thus, the mirthful laughter experience appeared to reduce serum levels of cortisol, dopac, epinephrine, and growth hormone, which suggested that these biochemical changes had implication for the reversal of the neuroendocrine and classical stress hormone response (Berk et al., 1989). In addition, Fry (1992) indicated that catecholamine activation can be intense during humor exposure and correlates with degree of laughter. With respect to the central nervous system, increased endorphin and catecholamine levels may be responsible for the beneficial effects of humor (Fry, 1986, 1992).

7.1.3 Humor and immune system

The earliest published study on humor and immune system was to investigate the secretory immunoglobulin A (IgA), a component of the humoral immune system found in saliva that is involved in the body's defense against upper respiratory infections (Bull et al., 1971). The study (Dillon et al., 1986) found that Salivary IgA concentration increased significantly after subjects viewed a humorous videotape and did not change significantly after they viewed a didactic videotape, which supported the idea that the viewing of humorous material can increase salivary IgA concentrations. What's more, the study also examined the correlations between coping humor and IgA concentration. The findings suggested that salivary IgA concentrations were directly related to subjects' perception of their use of humor as a coping device.

Based on previous studies, Lefcourt et al., (1990) evaluated the relationship between humor and immune-system functioning with a total of 100 female and 20 male undergraduates. The study investigated the salivary IgA concentration levels in subjects when presenting them humorous stimuli. It suggested that Salivary IgA levels increased for the experimental group, but for the control group, the Salivary IgA level remained stable. Furthermore, the subjects who had a better sense of humor had stronger increases in S-IgA level. In addition, three different studies (McClelland and Cheriff, 1997) with humorous and comparison videotapes as stimuli demonstrated that humorous stimuli greatly increased Salivary IgA, and the participants with good sense of humor, associated with higher baseline concentrations of Salivary IgA and with greater increases in salivary IgA in response to humorous video clips, reported lower severity of colds in the past twelve months and in the three months following the assessment. Although there are some studies demonstrating the significant increase of IgA in response to humorous stimuli, there are some other research which had very weak effects or even got the opposite conclusion. One study (Labott et al., 1990) showed that significantly lower Salivary IgA levels followed the humorous emotion expression and humorous emotion inhibition conditions. The other study (Njus et al., 1996) also failed to show significant effects of humor on S-IgA levels.

Apart from Salivary IgA, natural killer cell is also regarded as an indicator of immune system functioning (Bennett and Lengacher, 2009) and it is capable of killing a wide variety of cancerous cells including leukemia, carcinomas, sarcomas and melanomas (Herberman and Ortaldo, 1981). In order to investigate the influence of humor on specific neuroimmune parameters, a study (Berk et al., 2001) was conducted with 52 normal subjects' viewing a humor video for 1 hour, their blood samples being taken 10 minutes before, 30 minutes in the process, and 30 minutes and 12 hours after the humor intervention. The study found that the activities of natural killer, immunoglobulins G, A and M were raised, with several immunoglobulin effects lasting 12 hours into recovery from initiation of the humor intervention. As a whole, the findings indicated that modulation of neuroimmune parameters during and following the humor-associated eustress of laughter provides beneficial health effects of wellness and a complementary adjunct to whole-person integrative medicine therapies (Berk et al., 2001).

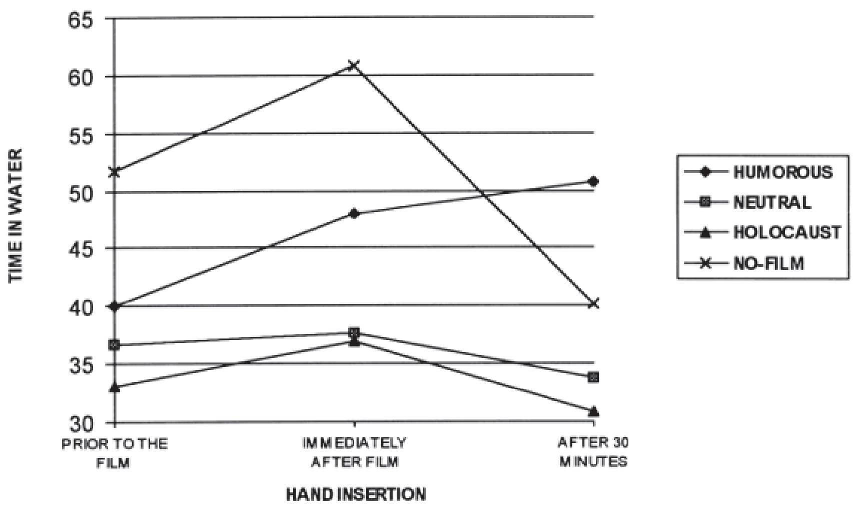
However, Martin (2001) reviewed a number of relevant studies on humor and immune system and found that there were significantly inconsistent conclusions among the studies. He attributed the inconsistency and irreplicability to the methodological issues. For example, some studies should include additional control conditions, like negative or positive emotional control condition. Therefore, more rigorous and theoretically informed research is needed before firm conclusions can be drawn about possible immune system benefits of humor and laughter.

7.1.4 Humor and pain

As early as 1928, researchers observed that laughter seemed to have analgesic effects on postoperative pain (McGhee, 1999), and there are more studies on relationships among humor, laughter, and pain nowadays, with the overall results favoring the existence of a link (Zweyer et al., 2004). For instance, a study (Cogan et al., 1987) conducted two experiments to examine the effects of humor on the pain by firstly dividing the subjects into four groups: comedy group, relaxation group, dull narrative group and no-treatment control group. The results showed that thresholds for both comedy group and relaxation group were higher than those for the dull narrative and no treatment groups. Then, in their second experiment, stimuli were more specifically categorized and the active distraction was also included. The results indicated that the change of pain threshold was caused by either humor or distraction. Then the subjects were divided into groups of comedy, interesting narrative, dull narrative, active distraction and no-treatment conditions. Consequently, pain thresholds were significantly higher than in the comedy group, which indicated that humor had effects on lowering the pain threshold.

Fry (1992) investigated that the pain reduction was caused by the relaxing effects of laughter, but it was not demonstrated in physiological data (Ruch, 1993). Other hypothesis related more to the effect of beta-endorphins caused by laughter and humor on the increase of the pain tolerance, but there was a study (Berk et al., 1989) which did not find the changes in the level of beta-endorphins after showing participants the humorous stimuli. Thus, in order to address what components of humor help to regulate the degree of pain tolerance, a research (Zweyer et al., 2004) correlated three essential factors in humor with pain tolerance. The first factor was about the variations of enjoyment of humor to investigate whether the cheerfulness, exhilaration and humor production had different effects on pain tolerance. The second factor was to investigate whether the degree of the enjoyment had influence on pain tolerance. The third factor was to investigate whether the disposition had the influence on pain tolerance. The pain stimuli in this experiment were the Cold Presser test, which was most used to measure the pain threshold, pain tolerance and pain sensitivity. Humor stimulus was a seven-minute segment taken from a humorous film, and the cheerfulness stimulus was the cheerful film without making subjects laugh or smile; exhilaration stimulus was to instruct to smile and laugh extensively in response to the film; humor production stimuli was to give humorous verbal comments on the film and then produce humor themselves. The experiment concluded that the improvement of the pain tolerance occurred in the whole process of watching the funny film and remained high for 20 minutes after the watching, and high cheerfulness subjects had greater pain tolerance compared with low cheerfulness subjects (Zweyer et al., 2004).

Though distraction is also used as a cognitive method to increase pain tolerance, humor is more effective than distraction, which was investigated by two experiments mentioned previously (Cogan et al., 1987), which indicated that humor, instead of distraction, was the essential element to increase the pain thresholds. Meanwhile, humor has also been applied to burn treatment (Kelley et al., 1984), dental treatment (Trice and Price-Greathouse, 1986) and a pain of children (Smith, 1986). A study conducted two experiments successively to examine the impacts of humor on cold-presser pain. In the first experiment (Weisenberg et al., 1995), three groups of subjects were shown different types of films: a humorous film, a repulsive film, a neutral film and a control group not watching any films. The findings suggested that both humor and repulsive groups increased significantly in pain tolerance compared with other groups. However, this experiment neglected the influence of the duration of the stimuli on the pain tolerance, since shorter exposure to any type of film may cause a distraction effect and longer exposure to the stimuli would show outcomes that were more related to humor. Thus, in their second experiment (Weisenberg et al., 1998), three lengths of duration types were included: 15 minutes, 30 minutes and 45 minutes and three different types of films (humorous film, holocaust film and neutral films) were employed as the stimuli. Each subject was given a baseline trial of cold-presser pain, a trial immediately following the film and a trial 30 minutes later. The conclusion suggested that a more increased pain tolerance was observed for the humorous film than the longer film regardless of types only after the 30-minutes waiting period (see Fig. 40).



Analysis indicated that the immersion after 30 minutes yielded a significant difference between films. As can be seen, the humorous film showed a continuous increase in pain tolerance as compared to the others.

Figure 40 Mean time (s) hand in water as a function of type of film (Weisenberg et al., 1998).

7.2 Humor and mental health

Humor may potentially influence both psychological and physical health through the positive emotion of mirth (Martin, 2008). Many research indicated that people who have relatively high scores on reports on sense of humor have the tendency to have lower scores on the depression, anxiety, and other types of mood disturbance, and higher scores on the positive emotions, optimism, self-esteem, morale, quality of life, and well-being (Lefcourt and Martin, 1986). Via the way of transferring the angles of seeing difficulties to distance from fixed mindset, people, who maintain a humorous outlook on life, had fewer possibilities to suffer from the cognitive distortions leading to worrying or depressing feelings (Kuiper, Martin, and Olinger, 1993).

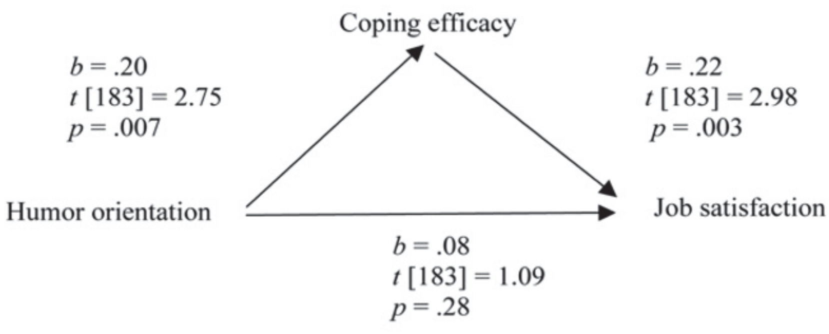
7.2.1 Humor as a coping mechanism

Humor is often conceptualized as a coping mechanism in that it involves a multidimensional, transactional process concerning how people handle stress (Erickson and Feldstein, 2007). Coping humor is reported to help release emotions in stressful conditions or help remain positive facing adversities (Lefcourt et al., 1995). Freud (1928) spoke of humor as being the "highest of the defense mechanism" and Mishkinsky (1977) referred to humor as a "courage mechanism." Psychiatrist George Vaillant (1977) regarded humor as "one of the mature and truly elegant defense mechanisms in human repertoire to deal with disadvantageous circumstances." In contemporary world, humor and laughter are frequently suggested as the means people can use to cope with life's difficulties (Ziv, 1988). Positive humor, as coping strategy, can alleviate the stress feelings through more positive appraisals and more realistic cognitive processing of the situations (Kuiper and Martin, 1998). Vaillant (1992) also suggested that humor is a more mature defense, predictive of greater levels of mental and physical health, life satisfaction, job success, and marital stability.

Humor has been investigated extensively for its ability to help individuals cope more productively with stressful situation (Bellert, 1989). A study by Kuiper et al. (1993) found that people with good-coping-humor abilities tend to see exams as learning opportunities rather than a negative threat, and, afterwards, they tend to adjust their expectations in a more realistic direction. Another study (Kuiper and Martin, 1998) explored that whether increased laughter can serve to moderate the affective impacts on negative life events, which essentially emphasized the function of humor as an effective coping mechanism. The findings revealed that individuals with a higher frequency of laughter did not show greater levels of negative affect as stressful life events increased. Especially for males, more stressful events were correlated with more positive affects for they laughed more frequently.

To further understand people's use of humor as a coping mechanism, a study (Nezlek and Derks, 2001) examined the relationships between coping with humor scale and people's daily social interactions and their psychological situation. Since enjoyment of the interaction was suggested to have negative correlations with depressive symptoms (Nezlek et al., 2000), the subjects in the study were required to maintain the Rochester Interaction Record for two weeks, including the degree of enjoyment for each interaction and the degree of being influenced in the interactions. The Coping with Humor Scale (Lefcourt and Martin, 1986) was employed to evaluate individual differences in using humor as a coping mechanism in the social interactions. The findings of this study indicated that people's use of humor as a means of coping with stress was positively related to how enjoyable their social lives were and to how confident they felt when interacting with others (Nezlek and Derks, 2001). The explanations for the experimental results lay in the optimistic view people had when they used humor as the coping mechanism, which eased the burden assumed by themselves and others, and showed more humorous forms of support, then causing enjoyment and confidence in social interactions.

Coping is believed to be an intrapersonal process, playing a significant part in communication exchanges (Burleson and Goldsmith, 1998). A study (Booth-Butterfield, 2007) examined the influence of humorous communication on handling stress from both work and academic demands among college students. The findings suggested that trait humor orientation had significantly positive correlations with coping efficacy, showing that the more employment of humor in communication, the more confidence people have to cope with job difficulties. The path analysis illustrated that the effects of humor orientation on job satisfaction was mediated by coping efficacy (see Fig. 41); besides, people with high humor orientation, compared with people with low humor orientation, believed their humor coping mechanism are more effective. Thus, the study concluded that personality trait of enacting humorous communication is positive in both interpersonal and career contexts (Booth-Butterfield, 2007).



The path analysis, using standard beta weights, demonstrated that the impact of humor on job satisfaction worked through coping communication. The overall model was significant. Humor was directly related to coping. Humor orientation was not directly related to job satisfaction, but rather influenced job satisfaction through coping.

Figure 41 Path analysis illustrating the relationships among humor orientation, job satisfaction and coping efficacy (Booth-Butterfield, 2007).

For the aged people, who are facing the degeneration in both physical and mental conditions, humor coping is one of the effective ways to help them decrease negative emotions. A study (Celso et al, 2003) examined the relationships between humor coping, health status and life satisfaction among older people. The findings indicated that health status and humor coping, and health status and life satisfaction were both significantly correlated, and as a result, humor as a coping strategy was available to older adults who were in better health.

Researchers investigated the degree to which coping humor, as one of the elements in sense of humor, can alleviate the negative mood by examining the correlations among three different aspects of humor: sense of humor, responses to humor and attentional bias toward humor (Moran and Massam, 1999). The findings indicated that coping humor was correlated with less negative mood ratings after watching the sad cartoon and humor bias was related with more positive mood ratings after watching the humorous cartoon. Thus, the study showed that coping humor helped people become preventative from the negative influences from negative stimuli by enhancing people's positive mood; attentional bias toward humor functioned as a psychological protection to help people focus on mood-enhancing stimuli in the environment.

7.2.2 Humor as a strategy to enhance positive mood

Positive mood can affect people's mind to increase creative problem solving and flexible yet careful thinking. An empirical study (Fredrickson, 1998) listed some supports for the positive effects brought by positive emotions: broaden the scope of attention, enhance the cognition, expand the scope of action, build physical resources, increase intellectual resources and develop social resources; besides, positive emotions undo the after effects of negative emotions and protect health. Moreover, positive mood results in a fundamental change in the breadth of attentional allocation to both external visual and internal conceptual space (Rowe et al., 2007). The experience of positive emotions contributed, in part, to people's abilities to control emotions either by accelerating cardiovascular recovery from negative mood or by finding positive meanings in negative circumstances (Tugade and Fredrickson, 2004).

Humor was illustrated to be an effective moderator to alleviate mood disturbance, such as depression, anxiety, anger, etc., to improve positive mood (Lefcourt and Martin, 1986). A study (Martin et al., 1993) lasted over two weeks and collected participants' data information from different scales of sense of humor and the Positive and Negative affect scale. The analysis results showed that, for the lower-sense-of-humor participants, greater levels of stressful events were greatly correlated with increased mood disturbance, while, for the high-sense-of-humor participants, even experiencing more stress, they did not show as great an increase in mood disturbance and they displayed significantly less negative affect towards the increasing of negative life events. Findings from the study indicated that sense of humor had significant moderating effects on the relations between stressful life events and mood disturbance. Besides the decreasing negative affect responding to negative events, the facilitative effects of humor also caused greater positive affect as positive experiences increases (Martin et al., 1993).

Individuals who frequently engage in humor may be less prone to various forms of emotional disturbance (Martin, 2008). Experiencing humorous situations leads to a shift toward a more positive emotional state, which may compete with the negative thoughts or emotions created by stressful event, resulting in a decreased psychological impact (Cann and Calhoun, 1999). Thus, having sense of humor can be a facilitating factor contributing to the well-being by improving positive personality and positive mood. Cann et al. (2009) proposed a model (see Fig. 42) indicating that sense of humor can play a role in the formations of a more general positive personality style, which mediates the perceived stress, giving rise to the improvement of both physical health and psychological health. In the research, scholars concluded that two self-directed humor styles, self-enhancing and self-defeating humor styles, can help to maintain higher levels of positive personality traits and positive mood, like optimism, hope and happiness, which decreased their stress level in lives.

A study (Cann and Calhoun, 1999) specifically examined the influence of a humorous external event and sense of humor on a stressor. The stressor was a stress-causing movie and, after the stressor, subjects received a treatment involving either a humorous videotape, a non-humorous videotape or waiting without distraction. Subjects' anxiety and affective states were both evaluated before and after the stressor. The results indicated that stressors increased the level of anxiety and decreased the positive affect, and humor treatment effectively lowered the level of anxiety and improved the positive affect compared to waiting condition, though non-humorous treatment also decreased anxiety, but did not raise the level of positive affect. The study also suggested that, among various measures of sense of humor, there was a common element of sense of humor that involved an appreciation for the personal and social utility of humor that may be closely related to emotional responses to life events (Cann and Calhoun, 1999).

To further investigate the acute effects of humor on mood and anxiety, a study (Szabo, 2003) recruited 39 participants, at weekly intervals, watching three times of a humorous stand-up comedy or a documentary video, or running or jogging at self-selected pace. State anxiety was measured before and after each experimental condition and psychological mood states were assessed. The findings indicated that both humor and exercise had significantly positive influence on psychological distress and humor exerted greater anxiety-lowering effects than exercise (Szabo, 2003). Thus, humor was concluded to be a very effective method to induce positive mood.

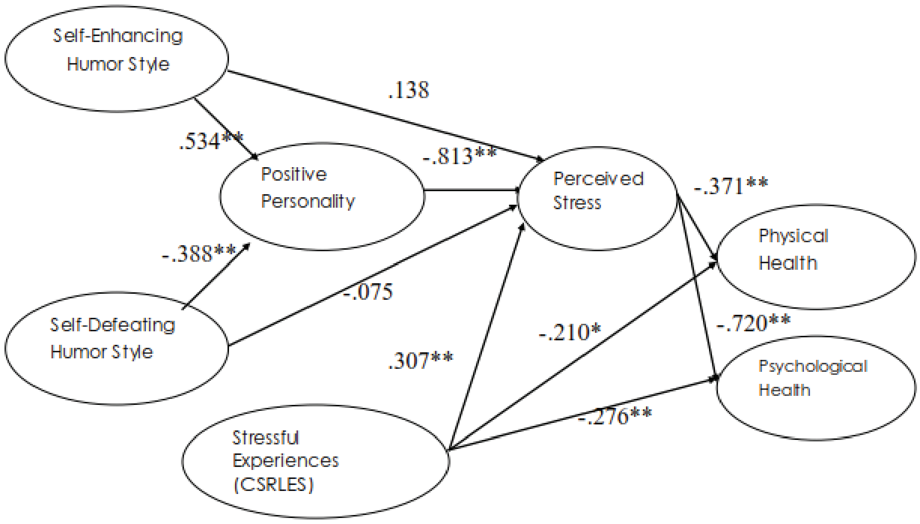


Figure 42 The model of two self-directed humor styles and positive personality ($p < .05^*$, $p < .001^{**}$) (Cann et al, 2009).

7.2.3 Humor as an intervention technique

For some people who meet difficulties in life, they refuse to accept the reality and also refuse the help from others for some reason, and consequently, long-time sufferings will do harm to their mental health. The timely and effective intervention will exert influences to help them enhance their mental states and physical states as well. There are many types of positive intervention, such as pharmaceutical intervention, humor intervention, patience intervention, courage intervention, empathy-related intervention, gratitude intervention, and so on. Depending on different circumstances, different type of intervention can be adopted to help people with stressful events, emotional problems, addictions, disorders, bad habits and even an immediate crisis, like self-destructive actions.

Humor, as an effective intervention strategy, can be used to alleviate anxiety and tension, encourage insight, increase motivation, create an atmosphere of closeness and equality, expose absurd beliefs, develop a sense of proportion to one's importance in life situation and facilitate emotional catharsis (Rosenheim, 1974), helping people to obtain optimistic view towards difficulties in life. Laughter is a main outcome of humor, so that humor intervention is greatly correlated with laughter intervention. A study comprehensively reviewed laughter literature to assess health-related outcomes elicited by laughter and suggested that laughter can be used as a kind of complementary / alternative medicine in the prevention and treatment of illness since there were evidence suggesting that laughter had some positive, quantifiable effects on certain aspects of health, including both physical health and mental health, such as muscle relaxation, heart protection, arthritis, type 2 diabetes, stress, anxiety, depression, coping strategies and so on (Mora-Ripoll, 2010) (see Tables 5 and 6).

Table 5 Effects of laughter Intervention on Health-related Physiological Outcomes (Mora-Ripoll, 2010).

Effects of laughter Intervention on Health-related Physiological Outcomes

Physiological Outcome	Results of laughter intervention
Muscle relaxation	relaxed muscle tone (Paskind, 1932) or H-reflex depression (Overeem et al., 2004)
Heart rate, respiratory rate, blood pressure, Oxygen levels	immediate increases in heart rate, respiratory rate and oxygen consumption (Fry, 1988) and the improvement in oxygen saturation level (Fry, 1971); an acute effect on systolic blood pressure (McMahon, et al., 2005); effective to lower the blood pressure as a long-term effect (109);
Effect on cardiovascular performance	increases in stroke volume and cardiac output, and decreased arterial-venous O2 difference and systemic vascular resistance (Boone et al., 2000); decreases in levels of serum cortisol and plasma von Willebrand factor (Xaplanteris et al., 2007)
Cardiovascular protection (long-term effects)	inverse association between propensity to laugh and coronary heart disease (Clark et al., 2001); fewer arrhythmias and recurrences of myocardial infarctions during cardiac rehabilitation (Tan et al., 1997); lowering the incidence of myocardial infarction in high-risk diabetic patients (Berk et al., 2008)
Endocrine stress markers and various hormonal measures	reduction in serum cortisol levels (Berk et al., 2001), increases in salivary chromogranin A levels (Toda et al., 2007); increases in urinary excretion of epinephrine and norepinephrine (Levi, 1965); reduction in serum levels of dopamine catabolite, epinephrine, and human growth hormone (Berk et al., 1989);
Neuroimmune parameters: salivary IgA, serum immunoglobuline levels, NK cell activity, leukocyte population	increases in natural killer activity (Bennett et al., 2003); relative increases in total leukocytes and specific leukocyte subsets (Berk et al., 2001)
Pain threshold and tolerance	increases in pain tolerance and discomfort thresholds (Weisenberg et al., 1998)
Effects in asthma and COPD patients	decreases in bronchial responsiveness in asthmatic patients (Kimata, 2004); reduction in hyperinflation in severe and very severe Chronic Obstructive Pulmonary disease (COPD) (Brutsche et a., 2008)
Effects in patients with rheumatoid arthritis	decreases in serum proinflammatory cytokine levels (Matsuzaki et al., 2005); increases in antiinfammatory cytokine levels (138); reduction serum interleukin-6 levels (Yoshino, 1996)
Effects in type 2 diabetes patients	influence in the gene expression profile in the peripheral blood leukocytes (Hayashi et al., 2006); prevention from the exacerbation of diabetic nephropathy (Hayashi et al., 2007) and diabetic microvascular complications (Nasir et al., 2005); contribution to amelioration of postprandial blood glucose elevation through a modulation of natural killer cell activity by upregulation of relating genes (Hayashi et al., 2007); lowering the serum epinephrine and norepinephrine levels, decreased inflammatory cytokines and C-reactive protein, and increased high density lipoprotein cholesterol in high risk diabetic patients with hypertension and hyperlipidemia (Berk et al., 2008)
Effects in atopic dermatitis patients	reduction in allergen-induced wheal reactions (Kimata, 2001); reduced allergen-specific immunoglobulin E production (Kimata, 2004); reduction in serum neurotrophin levels (Kimata, 2004)
Other: skin response, binocular rivalry, diaphragm electromyography	increases in galvanic skin response (Marci et al., 2004); cessation of binocular rivalry (Averill, 1969)

Table 6 Effects of laughter intervention on health-related psychological outcomes (Mora-Ripoll, 2010).

Effects of Laughter Intervention on Health-related Psychological Outcomes

Psychological Outcome	Results of Laughter Intervention
Effects on mood, stress, depression and / or anxiety symptoms	improvement in mood and positive affects in healthy adults (Foley, 2002); moderation in stress in healthy adults (Xaplanteris et al., 2007) or anxiety (Yovetich, 1990)
Effects on psychotic symptoms	reduction in hostility and depression/anxiety scores in schizophrenia patients and improvement in activation scores and social support (Saper, 1990); lowering the levels of psychopathology; and improved social competence (Gelkopf et al, 1994)
Performance, personal efficacy, coping abilities	increases in different aspects of self-efficacy, including self-regulation, optimism, positive emotions, and social identification (Xaplanteris et al., 2007); improvement in coping abilities (Saper, 1990)
Psychotherapy, group therapy, desensitization	prevention from risk of confrontation in addiction group therapy (Arminen, 2007); reduction in fear (Ventis, 2001)
Quality of life, patient care, well-being	improvement in quality of life in depressed patients (Walter et al., 2007); promotion in psychological well-being and enhanced patient care in different clinical settings (Erdman, 1994)

Simple exposure to humor and the positive psychological effects associated with enjoying humor will help counter the negative affective experiences (Cann and Calhoun, 1999). Over the past decades, psychoneuroimmunological research has repeatedly documented that various types of stressors lead to interactions among the neurological, endocrine and immune systems, which can decrease immune functioning and disease resistance (Zeller et al., 1996), The most common intervention cited was prayer, followed by humor (Bennett, et al., 2003). Bennett et al., (2003) conducted an experiment to explore the effects of humor intervention on stress and natural killer cell activity, and the findings revealed that the humor intervention can greatly lower the stress compared with distraction intervention, and good-humor-response participants had increased immune function post-intervention, also correlated with changes in Natural killer cell activity. The study concluded that laughter reduced stress and improved Natural Killer cell activity. Therefore, laughter can be employed as a very useful cognitive-behavioral intervention because low Natural Killer activity is linked to decreased resistance and increased morbidity in persons with caner and HIV disease (Bennett et al., 2003).

Humor produces laughter, which is one of the healthiest and strongest factors that maintain life equilibrium (Koo and Lee, 2015). For school-aged children, the abilities of humor appreciation and humor production increase with the development of cognitive ability and their employment of humor styles becomes more sophisticated with growing up. Humor plays an important role in the establishment of the interpersonal relationships, the development of cognition and the enhancement of the positive mood in the phase of childhood life. In this sense, humor is a crucially necessary toll for child resilience enhancement; it helps them take initiative to control their situations with their own abilities by encouraging them to view the situation more positively and with more affirmative attitudes (Rew and Horner, 2003). A study (Sim, 2015) completed a humor intervention program for school-aged children who had chronic diseases, 'atopic dermatitis and type 1 diabetes'. After the participants in the experimental group received 6-week-session of a 60-minute humor intervention, they showed significant decreases in behavior problems and increases in resiliency compared to the control group, which provided the evidence on the effectiveness of humor as an intervention for school-aged children with chronic disease.

Another study (Cai et al., 2014) aimed at evaluating the effects of humor intervention on recovering outcomes and their sense of humor among patients with schizophrenia, and concluded that the implementation of humor skill training can improve both recovering outcomes and sense of humor for schizophrenia patients who were in the recovering stage.

For older people, they experience more and more stressful moments as they face each day with pessimism and regret about the past (Ruthig and Chipperfield, 2007). They often see an increase in social isolation and loneliness due to fewer opportunities to socialize with the loss of peers and social roles, as well as physical limitations that my hamper social contacts (Morse et al., 2017). One method to improving the health and living states among the older people is the humor intervention. A number of humor intervention programs have been carried out to examine its effects on both psychological and physical states of old people. One of the researches (Ganz and Jacobs, 2014) summarized a number of relevant experiment results and indicated the positive effects of humor intervention on older people's physical and mental health. In detail, most of the experiments adopted 'randomized control trial' experimental design, and the types of intervention ranged from playing laughter video, sharing personal jokes, collecting humorous materials to laughing exercises and games. As for the outcome measuring, most experiments selected questionnaires and interviews with depression scale, health survey, cheerfulness inventory and life satisfaction scale. The vast majority of the experimental results showed significant differences in depression, insomnia, sleep, a state of cheerfulness, health conditions and life satisfaction between the old people who received humor intervention and the ones who didn't.

Elder clowns and group-led humor interventions have been shown to lower the level of chronic pain and increase psychosocial improvement, including better mental function, decreased depression, and general increased well-being in older adults (Berk et al., 2001). Improvisation engages cognitive functions, promotes narrative development, and relies on consensus-building with a group (Magerko et al., 2009), so improvisation comedy is a promising area and also a novel way integrating the benefits from both improvisation and humor to exert effects on the enhancement of older people's living states. A study (Morse et al, 2017) sought to explore the effects of humor intervention on older adults by involving them in a program named 'Humor Doesn't Retire', a comedy-based improvisation training, to characterize the benefits that older adults perceived following a series of humor-related course. The findings indicated the great benefits in increased positivity, increased sense of comfort, increased self-development, a feeling of blending into the social activities and enhanced problem-solving abilities, which suggested that improvisation comedy may be an effective mechanism by which older adults use to combat several geriatric syndromes, including depression, stress and isolation – all of which are detrimental to people's health.

For children and their parents who will undergo the operations, the humor intervention is very effective to alleviate their anxiety levels. A study (Berger et al., 2014) assessed preoperative anxiety in child-parent dyads, with subjects being divided into two groups: one received the humor intervention in the form of "Wacky Wednesday" and the other received usual care. The participants' heart rate, blood pressure and anxiety scores were measured on admission and just before transfer to the operation room. The results showed that children who received humor intervention had strongly lower anxiety level both on admission and before the operation than children in the control group, suggesting the effective intervention of humor on decreasing children and parents' preoperative anxiety.

In brief, as we have discussed previously, humor is a high-level complicated process involving the aspects of cognitive process, emotion arousal, social interactions etc. All of these aspects of humor have direct or indirect influences on emotional well-being and mental health. Though the positive physical effects caused by humor are controversial in different studies due to the methodology, the potential positive effects of humor on mental health through enhancing the positive mood are confirmative. A great number of laboratory researches have provided a considerable amount of evidence to corroborate the functions of humor as the coping strategy, the stress mediator, and the emotion-regulation mechanism. Therefore, the significant correlations between humor and both physical health and mental health imply the advantages of humor as an intervention tool to improve people's well-being, and the research of integrating it into the emotion related technical artifact will be helpful for people with negative mood to a great extent.

The emotion design concept proposed in the following content mainly involves humor intervention as the primary strategy to enhance the positive mood of the future artifact users. The elementary measurement method employed in this design concept rests on the brain-imaging techniques and different kinds of sensors (which will be detailed later), which can provide a large amount of data information connected to the artifact users' physical conditions and mental conditions before and after the humor intervention. Thus, the more comprehensive investigations into humor's influences on physical health and mental health, the more valid results we will achieve on the evaluations of the usage of the future artifact, because we have to build the design concept on the basis of a holistic understanding of both the Form-of-Life of the artifact users and the potential influences the artifact will have on them to make practical and effective artifact design.

8 AN INNOVATIVE EMOTION DESIGN CONCEPT FOR HAHA

8.1 The merger of EEG-based Brain Computer Interfaces (BCI) and Life-Based Design

If cognitive science should therefore study the mind not in isolation but in interaction with the physical world, then it is a natural second step to ask how to design artifacts in the world that best facilitates the interaction (Parasuraman and Rizzo, 2008). A practical and effective artifact design to promote the interactions between cognitive study and realities cannot lack the theory guidance and the combination with the updated technological contexts, besides precisely locating the burning problems which have serious negative impacts on people's living states. The Life-Based Design theory based on Human-Centered Design approach, requiring the comprehensive analysis of Form-of-Life on target people, is indispensable for a design concept in a holistic artifact design. Meanwhile, against the current technological background, the brain-imaging technique, like EEG, as a very advanced and sophisticated tool to objectively record and evaluate real-time Form-of-Life states in terms of brain responses, is also necessary to realize the artifact design with efficacy, and the interfaces between the brain and the computer are the prerequisites. Therefore, the merger between EEG-based BCI and Life-Based Design, an emotion design concept, integrating with humor research findings, is an innovative optimized way to bridge between the cognitive studies and real lives to provide solutions to the social issue of mood disturbance.

The EEG-based BCI and Life-Based design in this emotion design concept are very fundamental theoretically and complementary for each other methodologically. Specifically speaking, a practical BCI artifact must be designed on the basis of life, covering comprehensive factors of potential users, such as social factor, biological factor and psychological factor. The investigations into the social factor can mostly be reached by subjective self-reports or surveys, but by similar method, it is hard to achieve the objective observations into the biological factor and psychological factor. However, EEG, bears more objective and reliable advantages in observing the mental states of people with mood problems, making up the disadvantages of subjective recordings of brain responses. For instance, an EEG study (Henriques and Richard, 1991) explored the brain functions of 15 depressed subjects and 13 normal subjects by extracting the relevant frequency bands with three different reference montages and found that depressed subjects had less left-sided activation (more alpha activity) than did normal subjects, which was decided as a deficit in evaluating the biological factor in Form-of-Life analysis and can be used as an indicator in design artifacts related with people with depression. Another EEG study revealed that people with stable relative left frontal activities reported greater positive affects to positive films, while people with stable relative right frontal activities reported greater negative affects to negative films (Wheeler et al., 1993), which suggested that left hemisphere was more responsible for the formation of positive emotional states, while right hemisphere was more responsible for the formation of negative emotional states. This notion of "positive affect = left frontal" versus "negative affect = right frontal" asymmetry has been referred to as the "affective valence hypothesis" of frontal EEG asymmetry (Harmon-Jones and Peterson, 2009), which has great reference values in the evaluations of the emotion-related artifact design.

EEG is an effective and very frequently-used brain-imaging method, with high time resolution and relatively good space resolution, qualified for both an input tool to extract biological data and psychological data for Form-of-Life analysis and an output system to help evaluate the intervention effects on physical states and mental states. A major advantage of this merging methodology is its efficacy to examine human behaviors underlying neurophysiological level and reduce self-reporting bias in behavior research (vom Brocke and Liang, 2014). Thus, EEG-based BCI research should not only include the repair for disabled physical conditions, which already had mature research achievement, for example, artificial cochlea, and more importantly, it should pay more attention to the research in how to repair the emotional problems and even disordered mental state due to its powerful features in evaluating brain states.

EEG can be used to explore the mental activities behind human behaviors due to its sensitive responses to the neuronal activities in the brain responding to the outer stimuli. The basic working principle of it is to record the time-varying difference in voltage between an active electrode attached to the scalp and a reference electrode placed elsewhere on the scalp or body. Since the amplitude of the scalp-recorded signal is under 100 microvolts, most of the signal power will derive from rhythmic oscillations bellow a frequency of about 30Hz (Gevins and Smith, 2006). The electrodes of EEG are placed at different positions to record cortical and subcortical activities in frontal, parietal, occipital and temporal areas. Compared with other brain imaging methods, EEG device has its significant advantages: high time resolution to be possible to track the subtle changes in mental activities, easy to carry to any places, and suitable for continuous monitoring over long time. For example, Nexus EEG (see Fig. 43) is an EEG headset with semi-dry true Ag/AgCI electrodes, not requiring skin preparation or gels, and its lightweight and durable headset can quickly adjust to measure all of the frequency used 10-20 system positions, and fit a wide range of head sizes, meaning a cleaner and more comfortable experience for the users. But, this device also has its disadvantages, for example, relatively low spatial resolution, resulting in its limitations in anatomical localization of brain activities, though rough brain locations can be acquired. On the whole, to monitor and observe the artifact users in natural contexts, EEG is very practical, no particular requirements for the subjects. Despite some contaminating potentials which will influence the analysis of cognition-related EEG signals, such as eye movement, muscle activity and so on, multiple automated detection algorithms have been developed and different types of detectors have been applied, which can perform about as well as the consensus of expert human judges (Gevins and Smith, 2006).

Gevins and Smith (2006) outlined the degrees of five major determinants to which potentials arising in the cortex are measureable at the scalp in EEG: 1) amplitude of the signal at the cortex; 2) size of the region over which post-synaptic potentials occur synchronously; 3) proportion of cells in that region that are in synchrony; 4) location and orientation of the activated cortical regions in relation to the scalp surface; 5) amount of signal attenuation and spatial smearing generated by conduction through the skull and other tissue layers.

Because of different functional emphasis, two types of EEG: ongoing EEG and ERPs (Event-related Potentials), adopt different specific measures to investigate different tasks (see Tables 7 and 8). For instances, if the task is required to observe the emotional changes of people, ongoing EEG can be employed. Its slow-frequency waves (delta and theta band) should be particularly monitored (Bartholow and Amodio, 2009) and left or right frontal areas will be the regions of interest (Davidson, 1993); if the task is required to find the difference among people in understanding semantic incongruence, ERPs can be applied to mainly observe the features of the time window of 400ms (Kutas and Hillyard, 1980a, 1980b). EEG displays the functional significance to uncover the mental states of human being, and in turn, the presentation of the mental states helps researchers modify their research tasks and experimental stimuli to further investigate the Form-of-Life of target people and assist people in restoring their physical functions and even mental functions.

Figure 43 One of the examples of portable EEG products (https://www.biofeedback-tech.com/accessories/)

Table 7 Relevant ongoing EEG measures with corresponding research tasks (adaptive from Müller-Putz et al., 2015).

Research Task	**Relevant EEG Measure**
Ongoing EEG	
Mental load	Theta band (Fz) ↑ Alpha band (Fz, Pz) ↓ Smith & Gevins (2005)
Affective processes	Slow-frequency waves (delta and theta band) Bartholow & Amodio (2009)
Cognitive processes	Fast-frequency waves (primarily beta) Bartholow & Amodio (2009)
Positive affect	Left frontal asymmetry Davidson (1993)
Negative affect	Right frontal asymmetry Davidson (1993)
Memory performance, cognitive workload, fatigue	Alpha-theta ratio Berka et al. (2007)
Cognitive workload, task difficulty	Alpha-beta-theta ratio Kramer (1991)
Fatigue	Alpha spindles Simon et al. (2007)

Table 8 Relevant ERPs measures with corresponding research tasks (adaptive from Müller-Putz et al., 2015).

Research Task	Relevant EEG Measure
Event-related potentials (ERP)	
Selective attention, state of arousal	P1 Hillyard, Vogel, & Luck (1998)
Spatial attention, discriminative processing	N1 Hopf, Vogel, Woodman, Heinze, & Luck (2002)
Cognitive matching, detection of target stimuli, selective attention, feature detection (e.g., color, orientation, or shape)	P200 Freunberger et al. (2007)
Detection of a deviation of a concrete stimulus from an expectation, automatic novelty-sensing, hedonic preferences	N200 Folstein & Van Petten (2008)
Attention, memory, motivation, reward value, design preferences, fatigue, informativeness	P300 Begleiter et al. (1983)
Semantic processing, unconscious mental categorization	N400 Kutas & Hillyard (1980a, 1080b),
Perception of erroneous events, distress	Error-related negativity (ERN) Bartholow & Amodio (2009)

8.2 Mobile phone and mental health

Mere investigations into the Form-of-Life and the employment of EEG-based BCI are not enough to guarantee a successful design outcome, so we need to have well-grounded methods or tools utilized as the media to further connect users with the technical artifacts and facilitate communications between them. Information Communication Technology (ICT) is one of the innovations that have great effects on people's life in recent decades. For the great majority of people, especially for youth, they depend on ICT to accomplish most of their daily activities. ICT is no more a tool to assist them in their lives, but a popular way of life instead.

Among various devices of ICT, mobile phone is the one most frequently used nowadays: over half of the population in the United States owns a smart phone and 83% of these users do not leave their homes without it (Google, 2013). Recent research shows that even people with severe psychiatric disabilities and functional impairment, as well as many unsheltered homeless individuals, own and use mobile phones (Ben-Zeev et al. 2012). Mobile phone has become an indispensable technical artifact being blended into our daily lives and it carries more and more functions: talking, videoing, sending messages, education, paying, entertaining, taking photos, calculating, sending and receiving emails, navigation, shopping, gaming, banking and even more.

In addition to these commercial purposes, mobile phones also serve as instruments that can be utilized to help with health care. They can be carried on the person and allow for bidirectional communication and on-demand access to resources (Proudfoot, 2013). Average users check their phones as often as 150 times a day (Meeker et al., 2014), which reflects how much smart phone apps can generate, reward and help to maintain strong habits involving their use (Oulasvirta et al., 2012), so that apps are possible to implement cognitive and behavior interventions to improve users' physical health (Free et al., 2013) and mental health as well. Thus, 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 (Kazdin and Blase, 2011). Mobile phone health technology holds great potential for facilitating the management of emotional health through its ability to deliver flexible, user-oriented intervention and self-management tools; in particular, young people showed that they tend to choose nonprofessional or self-managed strategies to deal with their mental health issues (Rickard, 2016). Hence, mobile phone technology offers an unprecedented opportunity to unobtrusively track everyday behavior and regulate emotional state, all in real time (Randall and Rickard, 2013).

With the rapid upgrading of mobile phone technology and the development of apps, people have more choices facing a great number of mental health apps. The demand for mHealth apps is strong, as evidenced by a recent public survey that found that 76% of 525 respondents would be interested in using their mobile phone for self-management and self-monitoring of mental health if the service were free (Proudfoot et al,. 2010; Bakker et al, 2016). Using these apps, users cannot only remind themselves of their daily schedules, but also perform targeted intervention in their mental disturbance to enhance positive mood. Research showed that, through health apps, smartphones can be employed by users and providers for diagnostics, behavioral prompts, reminders and continuous illness monitoring and self-management programs that extend well beyond the boundaries of a physical clinic (Ben-Zeev et al. 2012).

Facing the emotional problems among people, the demand for face-to-face individual psychological counseling is already exceeding the supply of mental health service in most countries, signifying that new forms of intervention are needed to help people who suffer from mental problems (Kazdin and Blase, 2011). Many apps lacking experimental validation and efficacy are questionable. Bakker et al. (2016) indicated that a search of the Apple and Google app stores as of January 2014 revealed that none of these effective trials-supported apps was currently available to consumers, which implied a potential promising market waiting for being developed. The key issue is to firstly propose a practical and valid concept design, step by step, resulting in the prototypes and then the technical artifacts. The Life-Based Design with cognitive interventions will be an innovative design concept, being beneficial for people with negative mood by providing them with an easy-to-reach, professional and effective way to cope with the problem via mobile phones as the media.

8.3 A Concept design of humor implantation in mHealth

Life-Based Design (Saariluoma et al., 2016) elaborated on the process of the formation of a design concept and proposed some sequential steps to follow. The elementary step is to define the problem to be solved and then the comprehensive investigations are to be conducted by connecting to the Form-of-Life analysis on target population, including their conditions on biological factor, socio-cultural factor and psychological factor. Afterwards, a concept design will be proposed based on the previous findings and a detailed description of how the new design concept can improve the human actions will be illustrated. The third step is about the actual design process, in which the design plan is divided into sub-problems and these problems are to be solved on the ground of the literature basis against the current technical contexts. Then, the new knowledge or the innovative design will be worked out depending crucially on the needs and specific situations of the target users, and the relevant new technologies will be generated and how these technologies can be linked to the problems will be illustrated in great detail, including more concrete implementation plan and specific illustrations for each step forward, such as relevant technical staff involved and the equipment or devices employed. Finally, via the feedback from the potential users' experience or their evaluations, the proposed innovative design will be refined by the modification on the previous concept design; and after the round of this cycle among concept design – innovative design – user experience – refined concept design – refined innovative design, the final innovative design concept will be eventually built up (see Fig. 44).

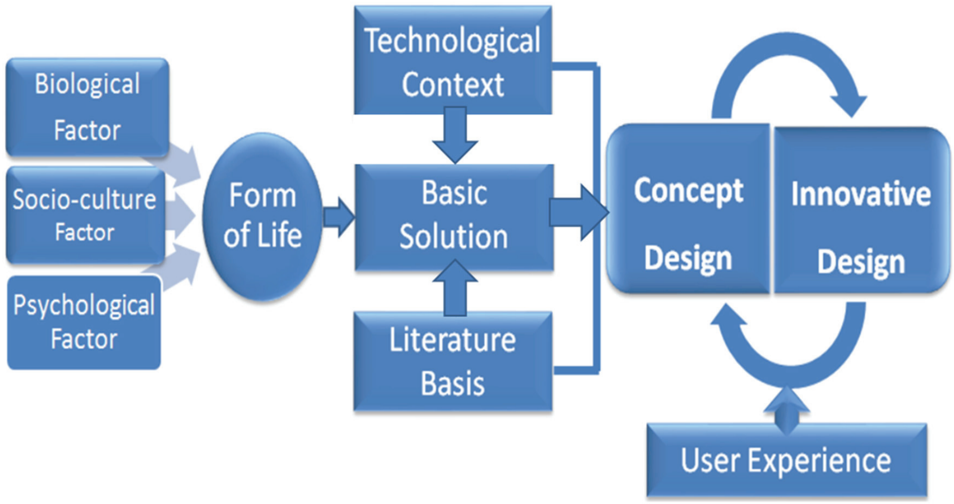


Figure 44 The flow of concept design and innovative design.

In this emotion design concept involving the overcoming of negative mood, humor research findings are adopted as the principal solutions. Humor concerns a high-level cognitive process related with emotional, behavioral, physical, psychological, and social aspects. As discussed previously, Freud (1960b) mentioned that humor can be seen as a specific defense mechanism, by which positive emotions can overcome the undesirable negative emotions in stressful situations. Beck (1979) 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. Laughter or mirth, caused by humor, makes people feel more relaxed, cheerful and less depressed and less stressful. It is one of many largely hardwired behavior patterns used by humans to communicate a wide range of positive or sometimes, negative emotions, with its prominent function related to joy. 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 specialized brain circuits (Gervais and Wilson, 2005). The research on the neural mechanism of humor processing found that exposure to a four-minute humorous film led to a significant reduction in reported feelings of anxiety relative to baseline (Moran, 1996). In addition, humor produces positive short-term emotional changes that are at least comparable if not superior to the effects of vigorous physical exercise (Martin, 2010).

Laughter is the concrete manifestation of the positive emotion of mirth caused by the appreciation of humor. The more intense of the emotion of mirth, the greater the laughter is. When people engage in humor and laughter, they tend to feel more cheerful and energetic, and less depressed, less anxious, and less tense. Hence, humor is regarded as the strategy to enhance positive mood and counteract negative mood. Meanwhile, different humor styles carry different influences on positive mood. Affiliative humor, used to create more harmonious bonding with other people, is prosocial and positive to enhance social interactions; self-enhancing humor is to boost confidence in difficult situations, usually having positive influence on mood. Besides, humor-related positive emotion of mirth is effective to help achieve basic tasks required for various relationships. The positive emotion of mirth accompanying humor replaces the feeling of being negative that would otherwise occur, enabling the person to think more broadly and flexibly and to engage in creative problem solving (Fredrickson, 2001).

A considerable amount of research mentioned before indicates that humor functions as an emotion regulation mechanism, reducing negative emotions and enhancing positive mood. In an experiment by Cann and his colleagues (Cann and Calhoun, 1999), they compared the effects of exposure to humorous versus a neutral videotape either after participants watched a film of negative feelings. The humorous video produced lower ratings of depression and anger and higher positive moods compared to the neutral video. Researchers concluded that the elevated positive emotions associated with humor may serve to counteract feelings of depression and anger, whereas the effects of humor on anxiety may be more cognitively mediated: humor preceding the stressor might work as a cognitive prime, changing the way subsequent events are interpreted and thereby reducing subsequent anxiety (Martin, 2010). On the whole, humor helps to cope with stress, smooth social interactions, increase creativity and enhance life satisfaction and well-being (Shen et al., 2015).

Depressed people are not easily amused, do not feel like laughing, and do not get any feeling of satisfaction from a jesting remark, joke, or cartoon (Beck and Alford, 2009). But, once depressive people are amused by humor, the elicited laughter or other humorous encounters, natural killer cell activity, immunoglobulin G and immunoglobulin M levels will increase for as long as 12 hours (Price et al., 2014), bringing about health outcomes. Besides, based on the theory of humor, the Incongruity Theory, the key of the three-stage model (incongruity detection, incongruity resolution and mirth) is to complete the appreciation of the humorous material by finding a new path to resolve the task. This predominating theory in this field illuminates the perceptual-cognitive processes of humor appreciation, which makes us view people, situations, and events from the perspective of two or more incongruous and seemingly incompatible perspectives at the same time and resolve the problem by understanding the new relations among the originally incongruous things. Thus, understanding humor material will help people with depression transform the old way of thinking and feel the relaxation of mood by finally laughing as well. From the perspective of neural mechanism, the activation of certain brain regions related to humor appreciation will stimulate the neurons of brain regions on depressive feelings, which will also play a part in reverting the depressive mechanism to the previous healthy mechanism.

People with psychological problems are often not very motivated to change, because their problem behaviors result in too many rewards, or because of the familiarity of the current situation, or it might be connected with being afraid of the unknown that the change will bring about (Van Bilsen, 2013). Whereas, 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. Hence, humor intervention, as a very acceptable and irresistible intervention method, can use the power of smiles and laughter to help people recover from negative mood by activating emotional-related brain regions and changing brain chemistry, boosting the immune system and stimulating corresponding brain regions related with depressive emotions. Furthermore, humor intervention can be used as both clinical and nonclinical treatment and prevention to enhance people's positive mood.

Mobile phones are fully integrated into modern life, which can facilitate the user's / provider's communication and the delivery of time-sensitive health information so that more researchers from different health disciplines are interested in developing evidence-based mHealth interventions for a range of physical and mental health conditions (Heron and Smyth, 2010). Therefore, by integrating today's technical context, such as the EEG-based BCI and mHealth, with the positive functions of humor on negative mood, an emotion design concept on the basis of Life-Based Design, is implanted into mHealth.

8.4 An emotion design concept: 5Rs Model

The design concept is a meta description of purposes and scopes as well as the principles of forms and functions, adding prescriptive knowledge to a certain system and constituting the guidance towards a nascent design (Adam et al., 2014). The goals of this emotion design concept are to enhance the level of positive emotion among people and improve their physical and mental health. One of the highlighting components of it is to record real-time biosignals, such as EEG signals, heart rate, eye tracking information and the like to transfer the analysed results, combining with the subjective investigations, into countermeasures against mood problems. A 5Rs Model mainly leveraging neuroscience as the basis was presented to design the conceptualization of the emotion-related technical artifact through using brain-imaging methods as both built-in functions and evaluation methods.

It is known that health care services continue to face more and more demand from an expanding population of consumer-patients and increasing cost in chronic disease management. Among the items in the health care services, long-term emotional problems rank the first, which results in the increasingly dominant role of technology and software in supporting the delivery of health care solutions (Carroll and Richardson, 2016). The enthusiasm for using mobile phones and other handheld technological devices for health care initiatives has led to the emergence of mHealth. New tools are needed to sense emotion and behavior in natural environments and provide controlled stimuli and responses in repeatable, measurable ways (Breazeal and

Picard, 2006). The current emotion design concept characterizing humor intervention in people with emotional problems via mobile phones will probably be supportive in the future to alleviate the tense situations in health care.

Most of the existing mobile phone apps in current app-market related to emotion usually employed a single measurement, for example, subjective self-report /questionnaire, to determine the user's emotional state. Though self-report /questionnaire is the most frequently used method to observe human's behavior, it is obvious that it has some unavoidable disadvantages. First of all, self-report /questionnaire involves recalling and evaluating the things which happened some time ago, so users' reports may be affected by misperception, misunderstanding, deceit, or a variety of memory and cognitive impairments caused by fatigue, drugs, aging, neurological or psychiatric disease, or systemic medical disorders (Rizzo et al., 2007). In addition, there is a time lag between subjective self-reports and real-time events, so the reliability and validity of self-reports are not dependable in providing objective evidence on evaluating the mood state.

People, in most cases, act differently in the laboratory settings compared with in the real lives because of their being aware about being tested, so the experimental results, to some degree, are unreliable. Real-time recording of real life is required to investigate the behavior of human being, which contributes to the time-series analysis, effective to detect cyclical fluctuations in behavioral variables, such as daily and higher frequency rhythmic patterns and more complex patterns that are indicative of dynamic or chaotic organization in the data (Anderson et al., 1998). Thus, to record subjects' naturalistic responses in the brain and body, it is optimizing to acquire objective investigations into the biological factor by brain-imaging techniques and various sensors.

With the assistance of more sophisticated and advanced technological methods, the real-time biological signs, such as brain signal, heart rate, blood pressure, skin conductance, eye tracking etc. are possible to be recorded simultaneously in real situations. The exponential development in brain-imaging techniques, computers, sensors, robotics and Artificial Intelligence, in power and performance as well as reduction in energy and cost, in combination with the ubiquity of communication technologies like the Internet, have resulted in the meteoric rise of smart connected devices: wearable monitors, smart watches, smartphones, etc. (Hird et al., 2016), which provide researchers with the most effective tools and media to help to collect biological data and give back the feedback information. EEG has been developed and upgraded to the type of being more portable and easier to use, which can be hidden inside daily wear, for example, a hat. Through locating regions of interests in the brain, the potable EEG will effectively collect signals related to brain activities to provide data for the supervision on the user's emotional states. Eye movements pervade visual behavior, being viewed as a significant part of human behavior and as a window on the perceptual and cognitive processes underlying behavioral performance (McCarley and Kramer, 2006). The visual scene is typically inspected with a series of discrete fixations separated by rapid saccadic eye movements and the information is collected only during the fixations. Visual input is suppressed during the movements themselves (McCarley and Kramer, 2006). The observed eye movements are controlled by a broad network of cortical and subcortical brain regions, including the parietal cortex, the prefrontal cortex, and the superior colliculus (McCarley and Kramer, 2006), and sophisticated eye tracking systems are now abundant, inexpensive, easy to use and often even portable (McCarley and Kramer, 2006).

Apart from portable EEG and eye tracking system, there are some other sensors which can be used to collect different biosignals. For example, JWatcher (http://www.jwatcher.ucla.edu/), an event-recording software, is available to be interfaced with video or automated sensor data to provide synchronized records of behavior and physiology that are essential to link overt actions underlying mechanism (Rizzo et al., 2007). Similar wearable devices can be put into clothing and heart sensors in bras. With the development of technology, multiple devices are being gradually integrated into a single device that is portable or wearable for people in need. The increase in the availability of sensors to measure common vital signs and behavior in unobtrusive forms worn on multiple body locations has led to the surge in commercial monitoring applications for wellness and health (Hird et al., 2016) (see Table 9). Users of these devices and sensors can record their real natural behavioral states without the limitations of time and places. However, strengths and weaknesses of different tracking systems, interfaces and synchronization between different data streams - and the pros and cons of different sensors (e.g., optical, audio, electromagnetic, mechanical), sensor calibration and drift, and data acquisition and analysis software - are important topics for further research (Rizzo et al., 2007).

Most of current emotion-related apps being used only include subjective emotion evaluation without offering systematic suggestions or solutions to the problem, which, to some degree, increases the stress of depressive people for feeling helpless, frustrated and hopeless. The emotion design concept in this monograph includes more objective, accurate and practical evaluation method and intervention strategy through employing multi-measurement tools to provide more comprehensive solutions to the problems. The principal design intention is to shift more attention and resources to preventive care and early intervention to help people detect the problems earlier and overcome the damage brought about by negative moods. It provides a real-time feedback and mobile-supervising system which is responsive to physical and mental signals associated with individuals and once the abnormal signs are detected, mobile interventions are simultaneously triggered and coping strategies will be provided to ease the emotion fluctuation.

Table 9 Examples of commercial and research and development (R&D) sensors for tracking vital signs and behavior (Madakam et al., 2015).

Examples of commercial and R&D sensors for tracking vital signs and behavior		
Vital sign or behavior	**Wearable location (form factor)**	**Environment location**
Blood pressure	Arm (cuff) Wrist (watch) Chest (clothing)	Bed Chair
ECG	Chest (phonecase, clothing, necklace) Waist (belt)	Bed Chair
Heart rate	Finger (ring) Ear (headset, earlobe clip) Chest (phonecase) Nosebridge (glasses) Forehead (hat)	Bed Chair Camera (face, mirror)
Pulse oximetry	Finger (ring, glove) Forehead (mounted sensor)	
Blood glucose	Waist (device) Eye (contact lens)	
EEG	Head (headset)	
Breathing	Chest (device, vest)	Camera (face)
Sleep	Wrist (watch) Ankle (watch) Head (headset) Chest (device)	Bed, mattress Bedside Camera
Body temperature	Wrist (watch) Forehead (patch)	Camera
Motion	Wrist (watch) Ankle (watch) Foot (shoe) Leg (stocking) Waist (belt) Chest (necklace)	Camera

The flow of data collection and data analysis in this emotion design concept consists of the following steps: data input, data analysis, data results output, psychological consultant's solution and humor intervention (see Fig. 45). In detail, firstly, the design concept being designed includes a moodkit, which includes optional subjective self-reports about the user's mood state. Via the moodkit, the subjective evaluations of users' mood states are transferred into data and collected to the analysis software (see Fig. 45 from ① and ③); the App of mHealth embedded in the mobile phone will be connected to the video function, and the facial expression recognition data will be also transferred to the data analysis software after the selfie (see ② and ④); then, by virtue of external portable equipment, including EEG (dry/wireless wearable electrodes), ECG (biosensors), or eye tracking system, the relevant real-time data on reading the specified material programmed is transmitted to the data analysis software (see ⑤, ⑥ and ⑦); after the comprehensive data collection on biological factor, psychological factor and social factor, the researchers will conduct Form-of-Life data analysis and evaluate the mood states compared with the individual's normal-standard mood state values set in advance based on the individual's big data; afterwards, the data analysis results will be passed to the researchers and psychological consultants for further integration and analysis (see ⑧); by comprehensive evaluations, the consultant will provide the solutions to counter the negative mood by humor intervention (see ⑨).

To generalize this emotion design concept, a 5Rs model is proposed, picturing the whole process of this Life-Based innovative design:

The 1st R: Record real-time biometric signals and physical signs

The external portable equipment, such as EEG, ECG, Eye Tracking system and facial expression recognition system (embedded in the app), will be employed simultaneously or selectively according to different situations to collect the real-time biometric signals and physical signs. The sensors in devices are realized by wireless connectivity and the availability of internet infrastructure, thus most applications have built-in Bluetooth technology to receive and transmit data via internet or Wi-Fi to a local, dedicated web or cloud server for storage (Hird et al., 2016). Take the EEG signal extraction as an example: emotional changes will be detected by the EEG analysis on investigations of the slow-frequency waves (delta and theta band) and left or right frontal areas are the regions of interest (Davidson, 1993). Besides, time windows of 400ms and 600ms are of values to detect the integration of language processing and Broca's area and Wernicke's area are both the significant regions of interests to detect language abnormalities. If the users have depressive inclination, the hippocampus and hypothalamic-pituitary-adrenal axis, related to brain reward pathway in the brain, should be monitored and measured about the degree of the dysfunction in these areas. There is one thing which has to be clarified: the actual EEG data extraction and analysis are far more complicated, which needs a team of professional researchers to set more precise standards on time, space and frequency dimension targeting at different cognitive tasks to detect user's emotion state. In addition, the normal standards of emotion states have distinct individual differences, thus, depending on the analysis of the user's personal big data, the normal standards can then be set on some specific factors, such as gender, age, personality and handedness. The development of advanced techniques for high-dimension analytics ranging from inference techniques to machine learning and Artificial Intelligence methodologies now provides powerful tools to identify patterns in the data (Hird et al., 2016).

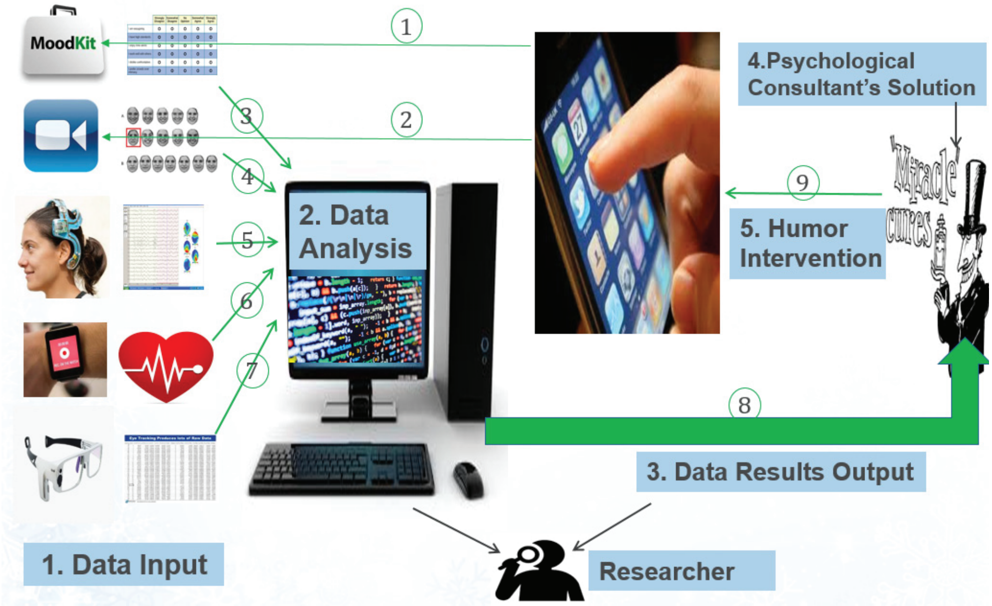


Figure 45 The flow of data collection and data analysis the emotion design concept.

The 2nd R: Retrieve mood state by subjective self-report

Though self-report way of measuring mood states has its drawbacks, which may give rise to the invalid evaluations due to its delayed recall and bias, this most frequently used mood state measurement has its great reference values to reflect biological, psychological and social factors of Form-of-Life to some degree. Thus, in this design concept, subjective self-report is used as auxiliary to the measurement of real-time biometric signals to supplement the absence of the brain-imaging tool or sensors. What's more, the moodkit adopted in this design concept will be a multi-dimensional mood scale. The relevant data will be evaluated compared with a preset standard values (extracted from big data analysis), and then the results will be combined with the results from biosignals to make the assessment on the mood state of the users.

The 3rd R: Repeat measurements across periods of time

In order to collect relatively stable and reliable data information, the previous measurements should be repeated across periods of time to get the dynamic information of the fluctuating mood states to form the individuals' big data and contribute to the setup of the individual's mood state standards. Furthermore, repeated measurements allow researchers to monitor how the mental states of people change over time, both long- and short- term observation. As for the specific data collection time and place, it depends on many conditions, including the specific situations (are the time and places suitable for the usage of the relevant equipment?), the evaluation results, the willingness of the users and so on, which is complicated to decide and needs more further research to set specific standards for different individuals.

The 4th R: Repair mood by humor intervention

Fostering humor by mobile phone under the supervision and instructions of psychological consults will be the principal way for the intervention, and the solutions will be based on McGhee's humor intervention program and 7 Humor Habits Program. The essence of fostering humor is to train people to own the capabilities of appreciating humor and producing humor to develop the cheerfulness in trait to realize the enhancement of positive mood. McGhee (1996) developed a humor intervention program that emphasizes strengthening key humor habits and skills in a hierarchical order (establish a playful attitude, laugh more often and heartily, create verbal humor, look for humor in everyday life, laugh at yourself, find humor in the midst of stress). The 7 Humor Habits Program is a standardized training, which can be completed individually through a manual or guided by an instructor in a group (Proctor, 2017) by mobile phone apps. The training of 7 Humor Habits in both healthy adults (Crawford and Caltabiano, 2011) and clinically depressed adults (Falkenberg et al. 2011) shows its effective increase in positive emotions and subjective well-being. Moreover, it decreases seriousness and negative mood (Sassenrath, 2001), depression (Crawford and Caltabiano, 2011) and anxiety (Proctor, 2017).

In the meanwhile, as mentioned before, EEG-based BCI in this design concept is not only a method to collect objective data, but also an effective tool to help analyze the data in comparison with the stored information and conduct the corresponding intervention. For example, prior to the intervention, the EEG data analysis will identify the brain areas relevant to the problematic emotions, and in the course of the humor intervention, the EEG data collection will be monitored to observe the changes in the time, space and frequency domain. After the intervention, through the data analysis, the findings of cognitive processes in humor appreciation will be applied to evaluate whether the intervention exerts desired influences on the emotional state. Specifically speaking, for the humor processing among normal people, there is a bilateral activation during the cognitive stage, left hemisphere network shows stronger activation in humor detection and comprehension, especially when related with verbal jokes, focusing on the speech brain regions. As for the affective component in humor appreciation, mesolimbic reward regions, with the highlights of amygdala, hippocampus and insular cortex, are the emphasis areas to monitor. In terms of frequency domain, for example, if the stimuli are verbal jokes, Beta should be paid more attention due to its close relations with language processing. These brain networks and particular brain regions are the focusing areas in collecting data, and at the same time, they are also the reference areas to evaluate the abnormality analysis and intervention effects. The actual situations will be more complex, and here is only the very brief illustration.

Last but not least, besides the human intervention of humor, the computational humor intervention is also included in this design concept. By running the computational humor models mentioned before, the App in the design concept will also bear the functions of joke understander and joke generator to immediately respond to the users' language input in humorous ways, which will not only help foster sense of humor of the users but also increase the communication opportunities in the virtual reality.

The 5th R: Remind users regularly to help develop humor into a part of life

Developing humor into a part of life not only helps people improve their social interaction skills, but, more importantly, decreases negative mood to enhance positive mood by applying the humor habits to the depressive situations. In short, the current design concept is to shift more attention and resources to preventive care and early intervention to help people detect the problems earlier and overcome the damage brought about by negative moods by providing a real-time feedback and mobile supervising system which is responsive to physical and mental signals associated with individuals. Once the abnormal signs are detected, mobile interventions are triggered and coping strategies are provided to help ease the emotion fluctuations. Above all, the attitudes of people towards depression are very negative and critical and they don't even want to make changes on their old habits. Due to fear of prejudice and discrimination, even when services are available, many people suffering from depression avoid or delay treatment, resulting in failing to receive the appropriate help they need (three out of four depressive people belong to this circumstance) (WHO, 2017). Whereas, the current design is embedded in smart phones, which have very good privacy-protection function, otherwise, people would not download bank system to make deals via smart phones. What's more, the humor intervention itself is very veiled, which will not only make the users or depressive people feel relaxed and free-minded but also shield themselves from other people's remarks. As we know, smart phones are especially popular among young people, who depend on them to a great extent in every aspect, so smart phones, as the tool of intervention, will naturally get young people closer and help them move out of fear from formal intervention. Depression leads to suicide, ranking as the second-leading cause of death among 15—29-year-olds after road traffic accidents, so much so that it must be attached to great importance, and effective intervention tools and solutions should be invented to mitigate the serious situations we are facing.

A major challenge but also the strength in the practicality of this emotion design concept built on Life-Based Design is its multidisciplinary nature. The design calls for a multidisciplinary team, where different-field researchers with different expertise work together (Saariluoma et al., 2016), involving cognitive science, neuroscience, psychology, sociology, physiology, health care, telecommunication and Information Technology. Thus, this emotion design concept requires a very high-level research team specializing in signal analyzing, psychological experiment design, programming, health care service, cognitive intervention, App development and so on. Furthermore, the standards of the equipment employed in this design should be set very high in order to achieve better performance, so the equipment should be sophisticated, effective, easy to operate and very portable as well. Meanwhile, conducting mHealth research with mobile phones is at the cutting edge of the health care research involving very a very sophisticated series of design research. Without realistic expectations and planning, integration of complementary sets of expertise in the research team, and an ability to remotely monitor, detect, and flexibly resolve obstacles as they arise, researchers will find mHealth projects to be daunting and difficult (Kane et al., 2016). This monograph tried to apply the findings of basic research to the practice and finally achieve the conversion between scientific study and daily technical artifacts. However, the conversion will of course need more specific in-depth research, test, re-research, retest and application.

9 GENERAL DISCUSSION

9.1 Summary

This monograph, adopting Neuroscience as the main methodology, elaborates on the research results produced by the joint studies between Design Science research and Neuroscience. The guiding theory in this emotion design concept is Life-Based Design theory, which places stress on the Form-of-Life analysis, including the investigations into the biological factor, psychological factor and social factor of the potential users, calling for a holistic research on people before the proposal of a particular design concept. The basic discussions on this emotion design concept start with the conceptual analysis of humor. Social component, cognitive component and affective component are three essential components to comprehensively understand the concept of humor, and at the same time, reflect the profound influences of humor on social relations, cognition and emotional states. Sense of humor is a greatly valued factor in personality, which is indicated to improve the mental flexibility, forge social bonds, cope with stresses, intervene in negative moods and even help make complaints. Humor plays an important role in business, politics, education and health care, being the potential remedy to release people's pressure, promote harmonious interpersonal environment and improve life satisfaction.

Humor-related theories are categorized into two groups in this monograph based on different functions. The Incongruity Theory is the most frequently used theory in this field, which is highlighted in this monograph, laying a very solid foundation for exploring the cognitive processing mechanism in humor appreciation. Different styles of humor, personality, gender, aging and sense of humor are all significantly correlated with the cognitive process in humor appreciation, so the relevant elaborations provide the research base with the holistic investigations. Right hemisphere and frontal lobe are concluded to be the key brain regions in humor appreciation through the studies on brain-damaged people. Taking the advantages of different brain imaging methods, such as fMRI, EEG and MEG, a number of studies analyzed humor processing mechanism, but scattered in different directions. This monograph systematically presents relevant research findings from the perspectives of space dimension, time dimension and frequency dimension, laying the solid foundation for its application to the design science.

From the perspective of space dimension, the technique of fMRI helps scholars localize specific brain regions in separating different stages in cognitive process in humor appreciation. Because of different types of stimuli, the brain regions activated in cognitive component in humor appreciation differ. In general, there is a bilateral activation during the cognitive stage, and left hemisphere network shows stronger activation in humor detection and comprehension, especially when related with verbal jokes, focusing on the speech brain regions. As for the affective component in humor appreciation, different experiments with different stimuli conclude similar brain areas: mesolimbic reward regions, with the highlights of amygdala, hippocampus and insular cortex. However, when probing into the functions of amygdala, the research found it is also greatly related with the cognitive component of humor appreciation: incongruity detection and incongruity resolution, suggesting the significant involvement of amygdala in both cognitive and affective component in humor processing. Any change in the humorous stimuli will elicit corresponding responses in relevant brain regions, though humor cognitive process has its elementary mechanisms. Brain connectivity analysis provides more precise picture of how neurons and neural networks process information by showing the correlations between different brain regions.

By utilizing the advantage of high temporal-resolution in ERPs, scholars have separated humor processing into different stages by extracting the feature of ERPs components (such as N400, P600 and LPP). These findings justify the validity of the Incongruity Theory, providing more evidence on further understanding the cognitive process of humor appreciation and at the same time, providing a very solid base for the applications of humor research in the reality. Different types of humor have different neural mechanisms in their cognitive processes, though all types of humor share the same processing stages, such as incongruity detection, resolution and mirth. During the incongruity detection, for verbal humor, the relevant language brain regions are activated and by comparison, for nonverbal humor, the visual search is spatially arranged, eliciting the visual cortex. Then going into the incongruity resolution, more complex processing is involved so that more brain regions related to attention, memory, problem-solving etc. are activated for both verbal humor and nonverbal humor. In the stage of mirth, all types of humor activate affective response, which are mainly correlated with reward system in the brain.

Though there are experiments having doubts on the gender differences in the cognitive process in humor, there are more experiments demonstrating the existence of it. The main difference between males and females in humor processing lies in the reward system in the brain, responsible for the affective response in humor appreciation. The ability of humor appreciation develops with the improvement of individual's cognitive ability, and the general tendency is to ascend across infancy, childhood, adolescence and younger adulthood, but it will then fall down a little bit during the late adulthood because of the slight decline of the cognitive ability. The employment of humor styles will go from nonexistence to existence, from single style to mixed styles and finally a certain humor style will be dominant and preferred by an individual. In contrast to younger adults, older adults have greater difficulty with humor comprehension due to age-related cognitive ability decline, but they enjoy humor more than younger people. They do not enjoy aggressive types of humor as much as the younger ones, and the elderly are especially sensitive to jokes referring to old age.

In the pilot study I conducted, all stimuli elicited P1/N1/P200 and N400 components, which are typical of ERPs to visually presented words. Effects were obvious on the P200 and N400 wave forms. And all jokes elicited P600 (500-700ms) and LPP (800-1500ms) components, which are typical of ERPs to humor appreciation. The behavioral results indicated that the sense of humor was significantly correlated with the ratings of nonjoke comprehension and nonsensical surprise degree rather than the ratings of the joke funniness like what we had commonly believed. The ERPs results suggested that P200 is specific to the neural mechanism of processing Chinese verbal humor, due to the essential distinctions between Chinese characters and alphabetic words. The findings also indicated that in humor processing, N400 effect is composed of two subcomponents: classic N400 and P400.

One of the humor-related cognitive theories, Script-based Semantic Theory (then developed into General Theories of Verbal Humor) provides the base for the development of computational humor. The listed computational models are mainly set up on the foundation of corpus and incongruity theory by decomposing the types of knowledge in jokes and many of them are effective in either being used as joke generators or joke understanders, contributing to the further development of Artificial Intelligence and also driving the improvement in Human Technology Interaction (HTI).

The investigations on humor's positive influence on both physical health, such as cardiovascular system, neuroendocrine system, immune system and pain tolerance, and mental health, as a coping mechanism and a strategy to enhance positive mood, drives the formation of an emotion design concept built on Life-Based Design, a 5Rs model. To move laboratory research into real lives, the studies on EEG and Brain Computer Interfaces (BCI) provide more possibilities and feasibilities to the application of this emotion design concept. Three essential factors of Form-of-Life analysis are elementary and the people with depression are exemplified to illustrate the way of conducting the investigations on Form-of-Life. To guarantee a successful design outcome, mHealth is integrated into the emotion design concept as the medium. The design intention is to shift more attention and resources to preventive care and early intervention to help people detect the problems earlier and overcome the damage brought about by negative moods. With the assistance of more sophisticated and advanced technical tools of BCI, the real-time biological signs, such as brain signal, heart rate, blood pressure, skin conductance, eye tracking, etc., can be recorded simultaneously or selectively in real situations, then combining subjective self-reports, and analyzed to achieve more objective and reliable evaluations on people's emotional states. Finally, by highlighting the real-time recording, feedback, and humor intervention, this emotion design concept is elaborated by integrating the relevant knowledge in this monograph.

9.2 Contributions

This monograph illustrated the fruitful results produced by the collaboration of Design Science research and Neuroscience research. The application of Neuroscience in Design Science research provides knowledge base, effective tools and objective evaluations to facilitate the creative design processes. The existing neuroscience literature explored close correlations between the functions of specific brain regions and cognitive processes, which are discussed in Design Science research also. In terms of the analysis on research methodology, Design Science research is basically composed of the elements of problem relevance, research rigor, solutions to problem, artifact design, design evaluation and reflection. Accordingly, the specific functions of Neuroscience research can help meet the demand of those elements. Neuroscience provides more objective, valid and reliable evidence on human being's cognition, which is greatly related to the relevance of the investigated problem people's cognitive process and helps to examine the research rigor and seek out the solutions to the problems in Design Science Research. What's more, brain-imaging techniques, used as the main research method in neuroscience research, are quite useful and effective to help to detect problem relevance, establish the rules for research rigor, explore the solutions to the problem and act as a tool in artifact design. For the step of design evaluation in Design Science, neuroscience research can take the advantage of its functions of both knowledge base and research tool to unbiasedly and objectively evaluate the designed artifact. The reflections on the usage of the designed artifact, on the other way round, examined the validity and reliability of the relevant neuroscience research results, forming a loop to improve both neuroscience research and Design Science research.

With the development of brain imaging methods, a great number of humor-related neural science experiments were done in scattered directions. This monograph, at the first attempt, tried to tease out relevant literature and categorized them based on different dimensions and research goals, which clearly showed the current research directions and focuses in this field.

Computational humor is a significant step toward Artificial Intelligence, however, there is no relevant literature summarizing the existing computational humor models and relating them to their theoretical base, cognitive linguistics. This monograph presented a picture about the current research situations in computational humor. What's more, it is also the first attempt to involve computational humor in the cognitive intervention in people's negative mood, which still needs more research to testify its effectiveness.

Rather than focusing on technology solutions in the early stages of this emotional design concept, we were more immersed in the problem itself to recognize the needs of the potential users via the analysis of Form-of-Life analysis, which prevented us from being constrained by software solutions in isolation. This design concept suggested a way of seeking practical and creative solutions to problems, which is a form of solution-based thinking.

In the past health care research related to emotion, there is an apparent lack of insight into how health care requirements are integrated by neuroscience to further improve the well-being among people. Besides, there is a lack of design concept to guide technical artifact designers in identifying health care needs, especially the mood enhancement needs to resist negative mood. To bridge the gaps, the emotion concept design in this monograph provided effective intervention methods resorting to the combination of Neuroscience and Life-Based Design.

The research in Brain Computer Interfaces (BCI) has attracted a lot of attention in recent years and most of the researches are related to some physical condition repair, such as cochlea implant and prosthesis. However, there is still no attempt to utilize BCI to help people with emotional problems. This monograph proposed the emotion design concept by integrating the emerging EEG-based BCI with Life-Based Design theory to provide a "three in one" system, including real-time recording, feedback and intervention strategy in one system, resorting to mobile phone as the main tool connecting the users and the system, for its strong impacts on modern life. A great number of cognitive experiments have been conducted in isolation, without connections with the actual application. This monograph tried to provide a design concept of bridging the cognitive experiments with real life. Figure 46 is the presentation of the basic form of this emotion design concept, which can be expanded to different forms with similar design objectives.

In detail, the first step in the Life-Based Design process is to define the problem being solved and the target population in need. The Form-of-Life analysis helps design researchers find the rules of life in the target population, showing their differences from other people in biological, psychological and social factors. For example, aiming at the people with negative moods, in collecting Form-of-Life data, both objective ways and subjective ways are employed to comprehensively reflect the true mental states of the target population. Objective way refers to the way of collecting real-time biological data, including facial expression recognition data, EEG signals, ECG signals, and eye tracking system data. Subjective way refers to the traditional self-reports to reflect the past-time response to certain events. The combination of these two ways has advantages over the single way to accurately picture the mood state in the brain. After precisely locating the problems of target population, depending on the current technical background and relevant literature, the design researchers propose the basic solution.

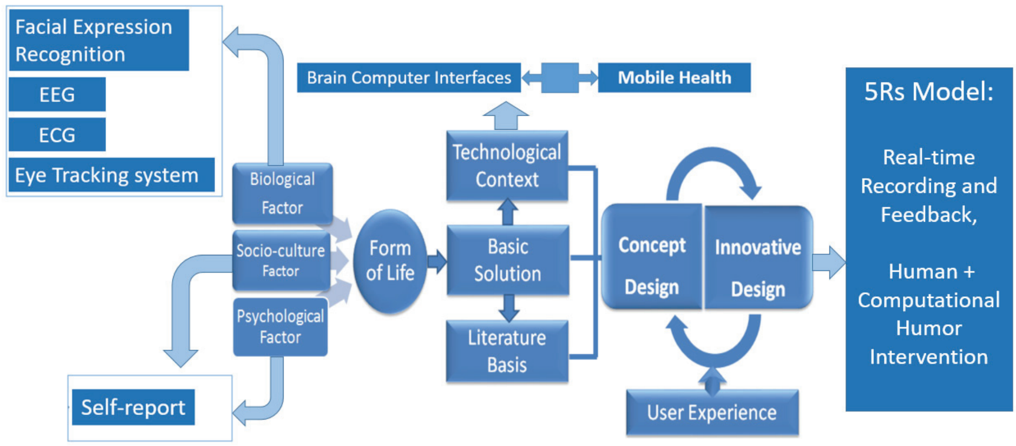


Figure 46 The design concept of bridging neuroscientific research and practicability.

With the development of neural imaging method, BCI becomes a dominant technique helping people solve both physical disabilities and mental problems. Resorting to mobile phone, the concept design is to outline what the supposed technology artifact could be like. In the process of the concept design, the relevant new technologies will be generated and how these technologies can be linked to the problems will be illustrated (Leikas, 2009). Furthermore, the concept design will be developed into innovative design, a 5Rs Model, with real-time recording and feedback and humor intervention from both human and computational models, by more concrete implementation plan and specific illustrations for each step forward, including relevant technical staff involved and the equipment employed. And then, after the firsthand experience of the users, the concept design is transferred to the innovative design, which represents the formation of a design concept bridging neuroscientific research and practicability (see Fig. 46). The 5Rs model is composed of adaptable hardware, software, telecommunication, Life-Based Design and human interfaces, which provided creative ideas in designing technical artifacts.

9.3 Limitations and future research

The monograph tried to present a whole picture including humor-related cognitive research and the design concept of humor-related technical artifacts. However, though there is a detailed grouping in analyzing different experiments of cognitive process in humor, it was hard to encompass all relevant materials. Thus, the generalizability in the monograph is limited. As for the pilot study introduced in the monograph, the individual difference must be one of the components which might influence the results and it was difficult to eliminate the semantic association for different stimulus conditions. The number of the subjects in this pilot study was a factor affecting the external validity, which is to be enlarged to get more solid conclusions in the following experiments.

A Life-Based BCI design is very complicated design thinking, needing a very high-level multidisciplinary cooperation and it is impossible to complete all the details of the concrete system without the team support. In addition, this design concept makes very high requests for the related equipment and operation system. Therefore, there are many specific implementations to be improved to possess better practicability. For devices, the most challenges are the development of signal processing, data analysis and interpretation to reduce noise and artifacts and ensure robust measurements in real-world conditions (Hird et al., 2016). Thus, an important caveat is that such techniques are sensitive to the data inputs - thus spurious signals or noise can lead to misleading interpretations that can have serious implications in the context of interventions and health care.

Aiming to translate the design thinking into a technical artifact, more research will be done to every detail and every link to specify more concrete and practical design plan. Furthermore, more investigations to the neural correlates related with negative emotions and humor intervention should be conducted to make further improvements on carrying out more effective and practical cognitive intervention. To go a step further, the future research needs to establish connections with more multidisciplinary teams to fuse the innovative ideas together for the achievement of the application and for really help people in need. What's more, the utility of such technologies will need to be validated in newly designed trials and approved under novel regulatory frameworks (Hird et al., 2016). The build – and – evaluate loop is typically integrated a number of times before the final design artifact is released into an application context for further evaluation through field study (Hevner et al, 2014). To examine the validness of the design concept, more build – and - evaluate loops should be conducted.

Digital health technologies will generate a tsunami of data that severely tests current data protection legislation and practice, encompassing numerous issues – privacy, permitted usage, security, storage, control, ownership and enforcement (Anthony et al., 2014), which is a prominent question worth considering in the design concept.

YHTEENVETO (FINNISH SUMMARY)

Tämä väitöskirja yhdistää suunnittelutieteen, lingvistiikan, psykologian, neurotieteen, tekoälytutkimuksen ja kognitiotieteen tutkimusotteita luodakseen menetelmiä, joiden avulla voidaan helpottaa negatiivisista mielialoista kärsivien ihmisten elämää. Välittömänä päämääränä on ollut kehittää huumoriin perustuva teknologiakonsepti, jonka avulla on mahdollista edistää masennuksen torjuntaa. Viime kädessä on kuitenkin ollut kyse suunnittelututkimuksesta ja neurolingvistisen ja neurotieteellisen tiedon soveltamisesta teknologiasuunnittelussa.

Perussuunnittelutieteellisenä viitekehyksenä väitöskirjassa on sovellettu elämäkeskeistä suunnittelua. Tämä tarkoittaa sitä, että teknologioiden suunnittelussa pyritään pelkän tekniikan suunnittelun sijasta kohdistamaan huomio ihmisten elämänmuotojen kehittämiseen. Teknologiasuunnittelu-ajattelun ydintä ei täten muodosta teknisen artefaktin konstruointi vaan tapa, jolla kohteena olevien ihmisten elämänlaadun nostaminen tarkoituksenmukaisesti suunniteltujen teknisten artefaktien avulla tulee mahdolliseksi.

Huumorin keskeiset komponentit, sosiaalinen, kognitiivinen ja affektiivinen, muodostavat tässä tapauksessa ihmislähtöisen suunnittelu-ajattelun lähtökohdan. Huumorianalyysin pohjana on tässä työssä käytetty ns. yhteensopimattomuus- eli inkongruenssiteoriaa. Se on kognitiivisen huumoritutkimuksen päälähestymistapoja, joten se voidaan luontevasti ottaa suunnitteluajattelun pohjaksi. Tutkimuksen empiirisen ytimen muodostaa aivokuvantamismenetelmien käyttö huumori-ilmiöitä tarkasteltaessa.

Aivokuvantamisen avulla on mahdollista paikantaa huumorin prosessoinnin kannalta tärkeät aivoalueet. Täten tämän tutkimuksen avulla on mahdollista saada tietoa siitä, miten humoristista informaatiota prosessoidaan. Huumori-ilmiöitä koskevien empiiristen ja teoreettisten tietojen pohjalta on mahdollista suunnitella tarkoituksenmukaisia teknisiä ratkaisuja, joiden avulla voidaan kehittää esimerkiksi huumorin monitorointiin sopivia teknisiä ratkaisuja kuten tarkoituksenmukaisesti lokalisoituja antureita.

Huumoritutkimuksen pohjalta on tunnettua, että huumorilla on masennusta ehkäiseviä vaikutuksia. Täten voidaankin ajatella, että huumoria edistävät teknologiat voisivat olla käyttökelpoisia eliminoitaessa masennusta. Yhdistämällä huumoria koskevaa kognitiivista, neuraalista ja semanttista tutkimusta tekoälyn avaamiin keinoihin on mahdollista luoda teknologiasovelluksia, jotka huumorin avulla voivat parantaa ihmisten fysiologista ja psyykkistä hyvinvointia.

Väitöskirjassa kootaan suunnitteluprosessin eri osa-alueet yhtenäiseksi suunnitteluviitekehykseksi. Täten tutkimus osoittaa kuinka neurokognitiivisen lingvistiikan ja elämäkohtaisen suunnittelun yhdistämisen kautta voidaan johtaa suunnittelutieteellisiä ratkaisuja. Tutkimus luo täten suunnittelumallin sille, miten neurotieteeseen ja neurolingvistiikkaan nojautuen voidaan tehdä ihmisten elämänmuotoja kehittävää elämälähtöistä teknologiasuunnittelua.

Tutkimus näyttää kuinka hyvinkin erilaisia ja näennäisesti etäisiä osaamisalueita, lingvistiikasta neurotieteeseen ja tekoälytutkimukseen, voidaan suunnitteluajattelun puitteissa yhdistellä. Tällä tavalla voidaan luoda ja soveltaa suunnittelumalleja, joilla kehitetyt tekniset artefaktit voivat parantaa tarkoituksenmukaisella tavalla ihmisten elämänlaatua.

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