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Physiological Changes to Humor and their Correlates with Affective States: A Preliminary Study

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Abstract

Background: *Humor produces laughter which contributes positively to psychological wellbeing, and the amusement effect is related to the affective state of an individual. Physiological responses to humor might help to characterize the influence of the affective state.*
Methods: *We invited 25 healthy participants to undergo the Mood Disorder Questionnaire, the Hypomania Checklist-32, and the Plutchik - van Praag Depression Inventory, and undertake the peripheral electromyography, galvanic skin response, and electrocardiogram tests to 20 Chinese acoustic jokes.*
Results: *There were no gender differences regarding questionnaire scales or the physiological indicators. However, the electromyographic change was positively correlated with depression scale in females, and with mania scale in all participants (especially in males); and the galvanic skin response change with depression in all participants. The response latency was correlated with the galvanic skin response change in females, and with heart rate change in all participants (especially in males).*
Conclusions: *We have demonstrated that individual's affective states influence the physiological responses to humor, which might help to illustrate the psychophysiological mechanisms of psychiatric disorders.*

Key words: Chinese joke; depression; humor; mania; peripheral neurophysiology

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1. Introduction

It is essential for human beings to enjoy humor (Martin 2007), since it increases body immune ability (Bennett & Lengacher, 2009), enhances physiological health (Savage et al., 2017), promotes learning (Lujan & DiCarlo, 2016), relieves life stresses and negative moods (Martin & Kuiper, 2016), and maintains psychological health (Ganz & Jacobs, 2014). Physiologically, there are several parameters which can be used to record the changes to humor. One example is the electromyography (EMG), which shows the electrical activity generated during muscle contraction (Lawrence & de Luca, 1983), especially the facial EMG, which is an index of affective reactions to diverse emotional stimuli (Borg et al., 2016; Šolcová & Lačev, 2017). The EMG activity of smile-related zygomatic major was enhanced, and those of frown-related corrugator supercilii decreased under pleasant or humor stimuli (Fiacconi & Owen, 2016; Larsen et al., 2003). The thyroarytenoid, lateral cricoarytenoid, and posterior cricoarytenoid laryngeal muscles had vigorous bursts of EMG activity during laughter (Luschei et al., 2006). The masseter muscle on the other hand, presented increased EMG activity during stress (Neureiter et al., 2017), and decreased one among less stressful conditions (Anna et al., 2015) or among remission period of mood disorders (de Oliveira et al., 2014). The second is the galvanic skin response (GSR), which represents the activation of sympathetic nervous system responsible for palmar sweat glands (Dawson et al., 2007), and it is a reliable marker of emotional arousal (D'Hondt et al., 2010; Gatti et al., 2018). Studies have shown that the GSR was increased in humor amusement (Britton et al., 2006; Shiota et al., 2011). The third is the heart rate, which is measured by electrocardiogram (ECG) and regulated by both sympathetic and parasympathetic nervous system, and its increase indicates an elevated sympathetic activity (Akselrod et al., 1981). In most cases, heart rate was decreased in response to humor (Kreibig et al., 2013; Overbeek et al., 2012; Shiota et al., 2011).

Humor related investigations were also conducted in clinical conditions. For instance, humor appreciation was impaired in autism and Asperger Syndrome (Lyons & Fitzgerald, 2004), alcoholism (Uekermann et al., 2007), schizophrenia (Falkenberg et al., 2007), social communication disorder, and paranoid personality disorder (American Psychiatric Association, 2013). In a twin study, alexithymia, being constraint in emotional understanding and expression, was less involved in using positive humor styles properly (Atkinson et al., 2015). Furthermore, scholars have employed humor therapy to treat anxiety and depression in different settings (Konradt et al., 2013; Low et al., 2014). There was a less pronounced readiness to react to funny stimuli (Falkenberg et al., 2011) and a deficit in humor processing (Uekermann et al., 2008) in depressive patients. The sense of humor was negatively associated with depressive mood in normal individuals (Madhan et al., 2013; Thorson et al., 1997), but increased sense of humor led to the elevated mood and laughter in patients with mania (Cassidy et al., 2001; Kendler, 2018). Therefore, patients with depression might react less, while those with mania might react more to humor.

Interestingly, López-Benítez et al. (2017) have documented that individuals with lower trait cheerfulness showed a greater heart rate decrease during visual amusing stimuli than those with higher cheerfulness. However, things might be different in clinically-defined emotional problems. Take affective disorders as an example, compared to healthy people, mania patients displayed higher muscle tension (Ganjekar et al., 2013; Swartz & Breen, 1990), which might be reflected by overactive EMG activity, and depression patients displayed reduced GSR and heart rate (Sarchiapone et al., 2018; Schiweck et al., 2018). A question therefore arises how the affective states (mania, hypomania, and depression) influence the physiological responses to humor. The current study was then designed for this purpose. As a preliminary study conducted in healthy volunteers, we recorded EMG, GSR, and ECG, as well as the Mood Disorder Questionnaire (MDQ, Hirschfeld et al., 2000), the Hypomania Checklist-32 (HCL-32, Angst et al., 2005), and the Plutchik - van Praag Depression Inventory (PVP, Plutchik & van Praag, 1987).

We firstly have hypothesized that when responding to humor, change of EMG is positively correlated with MDQ, and changes of GSR and heart rate are negatively correlated with PVP. On the other hand, there is a documentation paucity of gender difference on the peripheral physiological-responses to humor. The healthy males spent more time laughing than females under the same humor and heart rate was positively correlated with laughter duration in both genders (Buchowski et al., 2007). Male manics had higher sense of humor and higher motor activity than their female counterparts (Bhattacharya et al., 2011). We secondly hypothesized that males score higher on humor intensity, and their EMG change to humor is correlated with MDQ.

2. Method

2.1. Participants

We invited 25 participants (8 females and 17 males; mean age, 20.60 years with .58 S.D., age range, 19 - 21 years) from a Chinese university. All participants were required to be medication free three days prior to the testing. They were also confirmed to have no other confounding factors including schizophrenia, schizoaffective disorder, nor prior history of head injury, alcohol or tobacco abuse, psychoactive substance abuse, central nervous system inflammation, nor other neurocognitive disorders through a semi-structured clinical interview. The study protocol was approved by a local ethics committee and all participants gave their written informed consents.

2.2. Questionnaires

In a quiet room, participants were asked to complete three questionnaires as briefly described below.

A. The Mood Disorder Questionnaire (MDQ)

The MDQ (Hirschfeld et al., 2000) is made up of three parts, including 13 forced-choice (yes or no) questions to evaluate the presence of symptoms and behaviors related to mania or hypomania, with one question to determine whether two or more symptoms have been experienced at the same time, and one question to determine the extent to which symptoms have caused functional impairment on a scale ranging from "no problems" to "serious problems". Its internal reliability was .79 in a Chinese sample (Yang et al., 2011a).

B. The Hypomania Checklist-32 (HCL-32)

The HCL-32 (Angst et al., 2005) is a self-assessment instrument which consists of 32 items for detecting hypomanic symptoms. Individuals were instructed to answer the forced-choice (yes or no) questions about emotions, thoughts, or behaviors, and to answer questions with reference to the duration, the impact on family, social and work life, or people's reactions. Its internal reliability was .88 in a Chinese sample (Yang et al., 2011b).

C. The Plutchik - van Praag Depression Inventory (PVP)

The PVP (Plutchik & van Praag, 1987) altogether contains 34 items, each of which has a three-point scale (0, 1, 2) corresponding to depressive tendencies. Participants have "possible depression" if they score between 20 and 25, or "depression" if they score higher than 25. In a Chinese sample, its internal reliability was .94 (Wang et al., 2002).

2.3. Physiological test procedure

Participants were guided to an experimental room with dim light, and then were required to sit 100 cm in front of a computer screen. They were equipped with a headphone and attached with electrodes (see below). Twenty pieces of acoustic jokes in Chinese were presented to each participant in a randomized order. During the joke presentation, they were instructed to keep their head and body motionless. After each presentation, they were asked to report their perceived intensity of the joke (i.e., how funny the joke was) using a visual analogue scale, ranging from 0 (not funny at all) to 8 (most funny).

2.4. Humors

Firstly, three investigators of our study (also our co-authors) separately did some online searching and altogether had collected 100 pieces of jokes. Then funniness of all jokes was rated and voted by each investigator. Jokes that ranked into the top twenty were employed in our experiment. All these 20 jokes in Chinese have a punchline at the end of the story, and they were narrated by two native Chinese speakers in steady speed and with vivid and amusing pronunciation or intonation to generate humors. Average duration of all jokes is 12.75 sec ± .91 SEM. An illustration of the joke (a translation from Chinese) is: [A baby wolf was born a vegetarian with no interest in meat. But one day he was chasing after a rabbit. Mommy and daddy wolves were really happy about this, until the baby wolf caught the rabbit and said, "Hand over your parrot!"]

2.5. Recordings

A three-channel bio-amplifier (Model MP150, Biopac Inc., USA) was used to record the biosignals during the test and was connected with Ag-AgCl plate-electrodes. EMG was recorded using an EMG 100C amplifier and two electrodes with one placed on the right masseter muscle and one behind the right ear. EMG signals were amplified with the following hardware setting: Amplifier Gain: 2000; Notch: 50 Hz; Low-pass Filtering: 500 Hz; High-pass Filtering: 10 Hz. GSR was recorded using a GSR100C amplifier and two electrodes placed on the pulps of left index finger and left middle finger. GSR signals were amplified with the following hardware setting: Amplifier Gain: 5 μΩ/ V; Notch: 50 Hz; Low-pass Filtering: 10Hz; High-pass Filtering: DC. ECG was recorded using an ECG100C amplifier and three Ag-AgCl electrodes with two electrodes placed on the right arm and the left leg, and ground electrode on the right leg. ECG signals were amplified with the following hardware setting: Amplifier Gain: 2000; Mode: Normal; Notch: 50 Hz; and Low-pass Filtering: 100 Hz; High-pass Filtering: 0.5 Hz. Analog data of EMG, GSR and ECG were sampled at 1 kHz with an MP150 analog/ digital converter and recorded online with AcqKnowledge (version 4.2.0, BIOPAC Systems, Inc., USA) software for Windows.

2.6. Data analysis and statistics

Baseline traces of EMG/ GSR/ ECG were calculated for 5 seconds before jokes, and then averaged for 20 trials. During each trial afterwards, the response onset (the onset of humor comprehension) was determined as the maximal EMG derivative during the time period from four seconds before to four seconds after the ending of the punchline. After the response onset was determined, the response latency for one trial was defined by subtracting the time of punchline ending from the response onset. The average change of EMG/ GSR/ heart rate for one trial was calculated by subtracting that of two-second average before response onset, from that of five-second after (During the 5-s window after the response onset, participants were still keeping their laughing states). Later, the overall recordings of EMG/ GSR/ heart rate were averaged for 20 trials for each participant. The independent Student t test was employed to detect the gender difference of affective states, humor intensity, response latency, and overall physiological changes to humor. The relationships between changes of EMG/ GSR/ heart rate, humor intensity, response latency, MDQ, HCL-32, and PVP scale scores were assessed by the Spearman correlation test. The Fisher z test was employed to detect the significant difference of correlations between male and female groups. A p value less than .05 was considered to be significant.

3. Results

Each trace of the electromyography, galvanic skin response, and electrocardiogram showed humor-related responses clearly, and the example traces in a participant during one trial were illustrated in Figure 1.

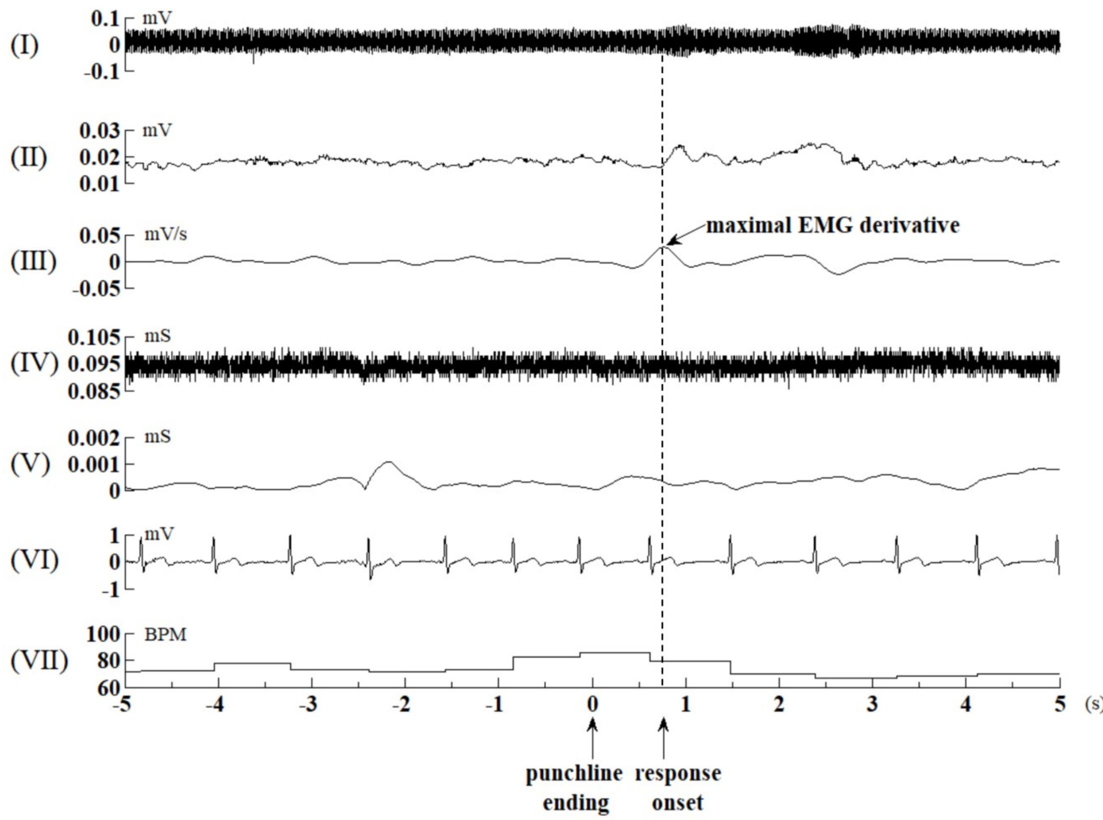

Figure 1. Illustration of electromyography, galvanic skin response, and electrocardiogram, their rectifications and quantifications, first derivative of electromyography, and response onset to humor in a participant: (I) raw electromyography; (II) rectified electromyography; (III) first derivative of electromyography; (IV) raw galvanic skin response; (V) rectified galvanic skin response; (VI) raw electrocardiogram; (VII) rectified heart rate.

Among all our participants (n = 25), scale scores of MDQ, HCL-32, and PVP were 5.60 ± .53 SEM, 18.48 ± .60, and 7.64 ± .88 respectively, the humor intensity was 2.75 ± .11, and response latency was .70 sec ± .11. The baseline EMG was 291.52 μV ± 135.78, and its change after humor stimuli was 2.84 μV ± 5.52; the baseline GSR was .0057 μS ± .0033, and its change was -.0012 μS ± .0011; the baseline heart rate was 74.97 BPM ± 1.48, and its change -.30 BPM ± .35 respectively. However, there was no significant difference of baseline EMG (t = 1.13, p = .27), GSR (t = .79, p = .44), or heart rate (t = -.19, p = .85) between male and female groups. Either, there was no significant gender-difference regarding MDQ (t = .45, p = .66), HCL-32 (t = .54, p = .60), PVP (t = -.66, p = .51), humor intensity (t = 1.64, p = .11), response latency (t = .42, p = .68), EMG change (t = .29, p = .78), GSR change (t = -1.16, p = .26), or heart rate change (t = -.21, p = .83) after humor (Table 1).

Table 1. Scores (means ± SEM) of affective state questionnaires, and humor intensity, response latency, and physiological changes to humor in male (n = 17) and female (n = 8) participants.

	Male	**Female**
Affective states		
Mood Disorder Questionnaire	5.76 ± .71	5.25 ± .73
Hypomania Checklist-32	18.71 ± .81	18.00 ± .82
Plutchik - van Praag Depression Inventory	7.24 ± 1.14	8.50 ± 1.36
Humor and responses		
Humor intensity	2.87 ± .13	2.49 ± .19
Response latency (s)	.74 ± .15	.63 ± .15
Electromyography (μV)	3.95 ± 7.62	.48 ± 6.56
Galvanic skin response (μS)	-.0021 ± .0016	.0006 ± .0006
Heart rate (BPM)	-.36 ± .48	-.19 ± .41

By contrast, the EMG change was correlated with MDQ in all participants (n = 25, $r = .42$, $p < .05$), especially in males (n = 17, $r = .58$, $p < .05$); and it was correlated with PVP in females (n = 8, $r = .76$, $p < .05$). Meanwhile, the GSR change was correlated with PVP in all participants (n = 25, $r = .44$, $p < .05$). The humor response latency was correlated with the heart rate change in all participants (n = 25, $r = .45$, p < .05), especially in males (n = 17, $r = .50$, $p < .05$); and it was correlated with GSR change in females (n = 8, $r = .79$, $p < .05$). The relationship between humor intensity and heart rate in males ($r = -.25$) differed significantly from that in females ($r = .65$; $z = -1.98$, $p < 0.05$). No other correlations were found in all participants, or in male/ female group (Table 2).

Table 2. Spearman correlation (r) between physiological changes to humor and affective states in male (n = 17) and female (n = 8) participants.

	Electromyography		**Galvanic Skin Response**		**Heart Rate**	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**
Mood Disorder Questionnaire	.58*	-.12	.11	-.18	.28	.15
Hypomania Checklist-32	.22	.64	-.10	.60	-.06	-.37
Plutchik - van Praag Depression Inventory	.04	.76*	.29	.67	-.25	.02
Humor intensity	.07	.42	.20	.35	-.25**	.65
Response latency	.11	.43	.19	.79*	.50*	.24

Note: * Correlation was significant ($p < .05$); ** Relationship significance between two groups ($p < .05$).

4. Discussions

We have explored the physiological responses to humor and their relationships with the affective states in both genders, but we failed to detect any significant gender-difference regarding affective states, humor intensity, response latency, or changes of physiological parameters. Nevertheless, the EMG change after humor was correlated with MDQ, and GSR change with PVP. Therefore, both our hypotheses have been partly confirmed.

Mania is characteristic of elevated mood or euphoria, overactivity with less relaxation, and increased optimism (Belmaker & Bersudsky, 2009), and it is associated with high level of motor activity with exposure to novel environment in clinics (Minassian et al., 2010). Therefore, in our study, when listening to jokes, participants with high MDQ score aroused their positive emotion and displayed intense motor activity of facial muscles. In our study, we recorded EMG on masseter, which was considered as the best attribute to differentiate neutral and non-neutral emotional states (Leon et al., 2004). The correlation between EMG change and MDQ was confined to males which was consistent with previous results that during manic episode, men had higher motor activity and humor sense than women had (Bhattacharya et al., 2011). In compliance with that muscle reduction was related to physical inactivity and female depressed patients did not significantly reduce muscle mass as their male counterparts did (Kahl et al., 2017), the EMG change was correlated with PVP in our female participants. In our participants, the GSR change was correlated with PVP, which was in line with that the GSR was increased in amusement (Britton et al., 2006; Shiota et al., 2011), and patients with non-anxious depression were more sensitive to facial happiness than those with anxious depression were (Berg et al., 2016).

In the meantime, the heart rate increased with response latency in our study, which might be due to that participants had the anticipation to hear jokes and then to laugh as a reaction, i.e., those who needed more time to understand jokes, might have more anticipation and this anticipation enhanced their reaction triggered by the jokes (Kunde et al., 2007). This correlation was confined to males, which might be due to that male had longer anticipation duration than female did, and their heart rate change was bigger with laughter duration (Buchowski et al., 2007). Moreover, GSR was correlated with response latency in our females, which might result from their low empathy level (Hampes, 2001), that was negatively correlated with skin conductance response (Li et al., 2018).

One should also bear in mind several design flaws of our current study. Firstly, our study is a preliminary design, and an investigation with a larger sample is needed to confirm our findings. Secondly, we only enrolled healthy volunteers, thus our results cannot be generalized into psychiatric patients. Thirdly, we only employed three physiological parameters to depict responses to humor, other biosignals such as the electrooculogram, blood pressure, or respiratory rate, might help to characterize the affective influences on the responses to humor more comprehensively. Fourthly, the 20 jokes were selected based on the judge evaluations and they were only repeated once in each participant, which might leave larger intra-trial variabilities in our tests. Fifthly, we did not enroll a control group of participants listening to neutral and non-humorous materials, whether our findings were unique to humor remains to be seen. Nevertheless, our study has offered some evidence that individual's affective states influence the physiological changes to humor, which might help to depict the psychophysiological undergrounds of psychiatric disorders.

Authors' Declarations

Regarding research work described in the paper, each one of our co-authors, Chu Wang, Xu Shao, Yanli Jia, and Wei Wang, declares that there is no conflict of interest, and has conformed to the Helsinki Declaration concerning human rights and informed consent, and followed correct procedures concerning treatment of humans in research.

Authors' Contribution

WW conceived the study, CW, XS, and YJ collected the data, CW and XS analyzed the data, CW, XS, YL, and WW discussed and interpreted the data, and CW and WW drafted the paper.

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