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Analysis of Relation between Psychological Stress and Intentional Facial Expressions Based on Bayesian Networks

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***Abstract* - This paper presents a gender-specific stress model to analyze psychological stress factors affecting intentional facial expressions. We extract three facial expressions (i.e., happiness, anger, and sadness) from the basic six facial expressions. Then we present a graphical model of the relation between these three facial expressions and the psychological stress factors. From probabilistic reasoning based on the observed values of each facial expression, the following trends were obtained. The stress models constructed by Bayesian networks showed trends of different stress factors between men and women in relation to expression levels and psychological stress. The stress models appeared on happy faces of "lassitude" factor in men. The angry faces of "displeasure and anger" were affected by stress factors in women. Furthermore, the influence of "displeasure and anger" readily appeared in the upper part of the face when expressing "anger". In addition, the influence of "lassitude" strongly appeared in the lower part of the face with the expression of "sadness", in the upper part of the face with the expression of "happiness".**

Keywords* - *Bayesian networks; Self-organizing maps; Adaptive resonance theory; Expression levels; SRS-18; Intentional facial expressions

I. INTRODUCTION

Modern human life has become increasingly convenient along with the rapid development of our advanced information society. However, we are sometimes confused amid the plethora of information spreading around us. Products and artificial environments that we do not want to use are useless, even if they might be convenient. Using unattractive products makes us feel uncomfortable and stressed. Anyone might feel stress if forced to use unsatisfactory products.

Modern society is full of stress. Numerous people live their lives with various stressors: factors that cause stress. Stress is a biological reaction that develops when one confronts a psychological or spiritual stressor. Reactive processes of people interacting with the environment signify individual cognitive processes that are involved in biological reactions and physiological processes [1]. Figure 1 presents three indices used for human measurements in the areas of biology, psychology, and action. All require the consideration of individual processes when a person is subjected to stress. Moreover, we can posit a psychological index that shows stress to be psychological. As Figure 1 shows, various somatic symptoms appear with gastralgia and breathless states when stress accumulates. Stress appears from a psychological state when one experiences frustration and unease. In addition, stress is manifested in actions such as the increased consumption of alcohol and cigarettes. Stress affects the brain. Usually, the human brain responds effectually to maintain mental and physical balance. However, excessive stress can trigger mental illness such as depression [2]. Because it can be difficult to conceal stress, faces are often described as a window by which one can discern information of various types such as the state of a person's mind and health condition. Especially, facial expressions can reveal aspects of internal psychology, reflective emotions such as delight, anger, sorrow, pleasure, and the existence of stress. Close friends and family members communicate while interpreting stress from conditions and changes of facial expressions.

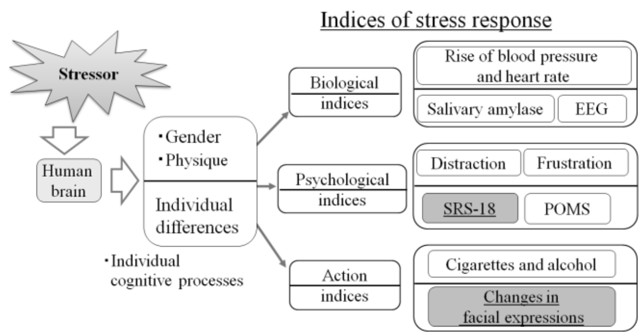


Figure 1. Background.

For this study, we specifically examine intentional facial expressions. Moreover, we set the upper part, lower part, and whole parts of the face as regions of interest (ROIs) to address static and dynamic diversity, as defined by Akamatsu [3]. We quantify the relation between facial expressions and psychological stress using Bayesian networks (BNs), which can describe stochastic relations of events as a graphic structure. For our evaluation experiment, we create stress models by gender. Then we analyze stress factors and stress elements in facial expressions of various types: happiness, anger, and sadness.

This paper is presented as the following. We review related work to clarify the position of this study in Section II. In Section III, we explain relations of psychological stress and facial expressions by FESCs that quantitatively represent individual facial expression spaces proposed in a previous paper. In Section IV, we explain our originally developed facial expression datasets including stress measurements and describe the method to capture facial expression images, preprocessing, classification of facial expression patterns with self-organizing maps, integration of facial expression categories with fuzzy adaptive theory. We describe how to create a model of stress elements using Bayesian Networks in Section V. We show analytical results of stress elements models for men and women in Section VI. In Section VII, we estimate stress factors using a male and female model with emphasis on facial parts effect of facial expressions. Finally, we present conclusions and intentions for future work in Section VIII.

II. Related Studies

Existing methods for measuring stress are divisible into two types: contact type and noncontact type. Using findings demonstrating that stress can affect amylase secretion in saliva, methods for quantifying stress have been proposed. Many products have been marketed based on such findings [4] [5]. In association with autonomic nerve activity and stress, many analytical studies of heart rate variability have been conducted. In fact, many devices have been developed and used in research and clinical practice [6] [7]. Numerous reports describe the correlation between stress and neural activity of the cerebrum. Particularly, electroencephalography (EEG) is a method that has been studied for many years. Studies using EEG have been performed in the context of the psychological state, such as attention and concentration, stress, and anxiety [8] [9]. As a new functional brain analysis method, near-infrared spectroscopy (NIRS), used for measuring cerebral blood volume changes locally and non-invasively, is also attracting attention as a stress measurement method, which indicates that the activity of the prefrontal cortex has changed significantly [10]. However, the methods for objective comparisons that are useful to identify the most suitable approach for stress measurements is extremely complex because each researcher has a different perspective: the type of stressor used in their experiments differs for each approach. In addition, methods using physical contact generally require a hardware interface.

Stress measurement checking using a questionnaire form is a popular noncontact measurement method. The Profile of Mood States (POMS) [11] is an inventory that is recognized worldwide, although its results cannot generally be compared because the target attributes differ. POMS consists of 65 items. The brief version of POMS consists of 30 items [12]. Actually, POMS becomes extremely burdensome if one incorporates images of facial expressions. Suzuki et al. developed the Stress Response Scale-18 (SRS-18) [13], which is useful for widely various subject ages. SRS-18 comprises 18 items and measures psychological stress encountered over a short time. Moreover, SRS-18 shows highly discriminative capability in high stress and low stress groups. Although most existing stress evaluations are aimed at the assessment of clinical conditions, numerous questions of the SRS-18 are related to events that normal people encounter on a daily basis.

Facial expressions and their intensities differ according to mental state, context, situation, etc. We actively use those differences to take facial expression images of each subject over a long term. We are aiming at describing and quantifying the relations of psychological stress and intentional facial expressions from temporal changes of long-term facial expression datasets. The degrees of expression levels differ among people and their feelings at any particular time. Therefore, the SRS-18 appears to be an optimal and helpful inventory for use in assessing facial expressions because of the measurement of physical and mental reactions and smaller number of question items.

III. Relations of Psychological Stress and Facial Expressions

An appropriate amount of stress improves abilities of concentration and engenders work efficiency. However, excessive stress produces psychosomatic abnormalities because of humans' limited adaptive capability. The degree to which one feels stress effects reportedly varies subtly in similar environments because of individual differences from conditions and tolerance of stress [14].

Therefore, it is necessary to measure the state of stress in individuals. Furthermore, it is necessary to take steps to improve a bad stress state soon after it occurs [2]**.** Therefore, we must be able to assess a person's emotional state while considering the corresponding relations to biology, psychology, and actions for stressors of various kinds. The relations between the changing expression intensity and psychological stress with facial expressions can be verified from their psychological and behavioral characteristics. We can assess expressions of individual facial expressions using Facial Expression Spatial Charts (FESCs) [15], which were proposed as a new framework to describe facial expression spaces and patterns of expressive intensity constituting each facial expression. Facial expression spaces are spatial configurations of each facial expression that are used to analyze semantic and polar characteristics of various emotions portrayed by facial expressions [4]. They represent a correspondence relation between the physical parameters that present facial changes expressed by facial expressions and the psychological parameters that are recognized as emotions. Our experiment results suggest the influence of psychological stress on facial expressions. For this study, we create a model of stress elements for individuals of both genders using BNs. Then, we graphically analyze the interdependence between psychological stress and facial expressions. For this study, we designate a parameter of expression intensity that characterizes facial expressions quantitatively.

IV. DATASETS

For this study, we constructed a dataset to assess facial expression changes. We measured the psychological stress of a subject showing facial expression changes using SRS-18. Then we compared the results to the facial expressions.

A. Facial Expression Images

We set the time period during which we measured facial expressions to construct individual models of stress elements. We constructed an original and long-term dataset for the specific facial expressions of one subject. For the experiment, we created original facial expression datasets from 10 subjects, with each dataset including images with three facial expressions: happiness, anger, and sadness obtained at one-week intervals during 7-20 weeks. The subjects were five women (Subjects A, B, C, and D were 19; Subject E was 21) and five men (Subjects F and J were 19; Subjects G, H, and I were 22), all of whom were university students. The order of facial expressions in a single measurement is happiness→anger→sadness. When taking images of each facial expression, the same expression is repeated three times based on neutral facial expressions during the image-taking time of 20 s. We previously instructed subjects to express an emotion three times during the image-taking time. One set of data consisted of 200 frames with the sampling rate of 10 frames per second.

We set the region of interest (ROI) to 90 × 80 pixels, including the eyebrows, which all contribute to the impression of a whole face as facial feature components. We set the ROI of the upper part to 40 x 80 pixels including the eyebrows, which contribute to the impression of upper facial parts as facial feature components. We set the ROI of the lower part to 50 × 80 pixels including the mouth, which contributes to the impression of lower facial parts as facial feature components.

B. Target Facial Expressions

We set three facial expressions of object facial expressions because the facial expressions are acquired over a long term for our study. We strove to reduce the load on subjects. We selected happiness, anger, and sadness from six basic facial expressions described by Ekman [16]. He asserted that Japanese people show disgust by smiling to conceal their true emotions. Therefore, we consider that it is difficult for subjects participating in this study to express disgust. The emotion of fear is a rare feeling in daily life. In the opinion of subjects, it was often stated that they are not

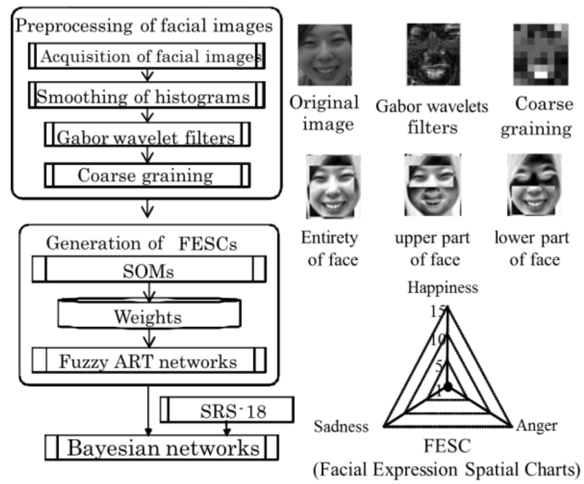


Figure 2. Procedure of the proposed method.

aware of how they appear when feeling fear. Therefore, we do not record fear among the facial expressions. Surprise can readily occur along with fear, happiness, solace, anger, and despair [16]. Therefore, we do not include surprise among the recorded facial expressions because it invariably translates into complex facial expressions.

Our target facial expressions are therefore happiness, anger, and sadness, which include the geometry of each quadrant of Russell's circumplex model [17].

C. Stress Measurement

Psychological stress reactions are anxiety, anger, lassitude and difficulty in concentrating, which are encountered on a daily basis when one is affected by stressors. Our measurements are three robust stress factors: "depression and anxiety", "displeasure and anger", and "lassitude". Subjects respond on the check sheet using four responses for 18 items, answering with responses from "Completely different" to "It's correct". Each answer receives a score of 0–3. High point totals signify a higher degree of stress. Moreover, stress levels are represented by consultation value Level 1 (weak), Level 2 (normal), Level 3 (slightly high), and Level 4 (high). For this paper, we define the reported values as stress levels. For this experiment, we measured stress values using the SRS-18 and took facial expressions of 10 subjects. To avoid influencing the facial expressions, we did not report any score to subjects. Moreover, subjects recorded their responses in accordance to the SRS-18 scale before recording facial expressions.

D. Extraction of Facial Expressive Intensity

Figure 2 portrays a flow chart of our proposed method. Features are emphasized using Gabor wavelet filters in the preprocessing of input images. For extracting and normalizing the topological variation of facial expressions,

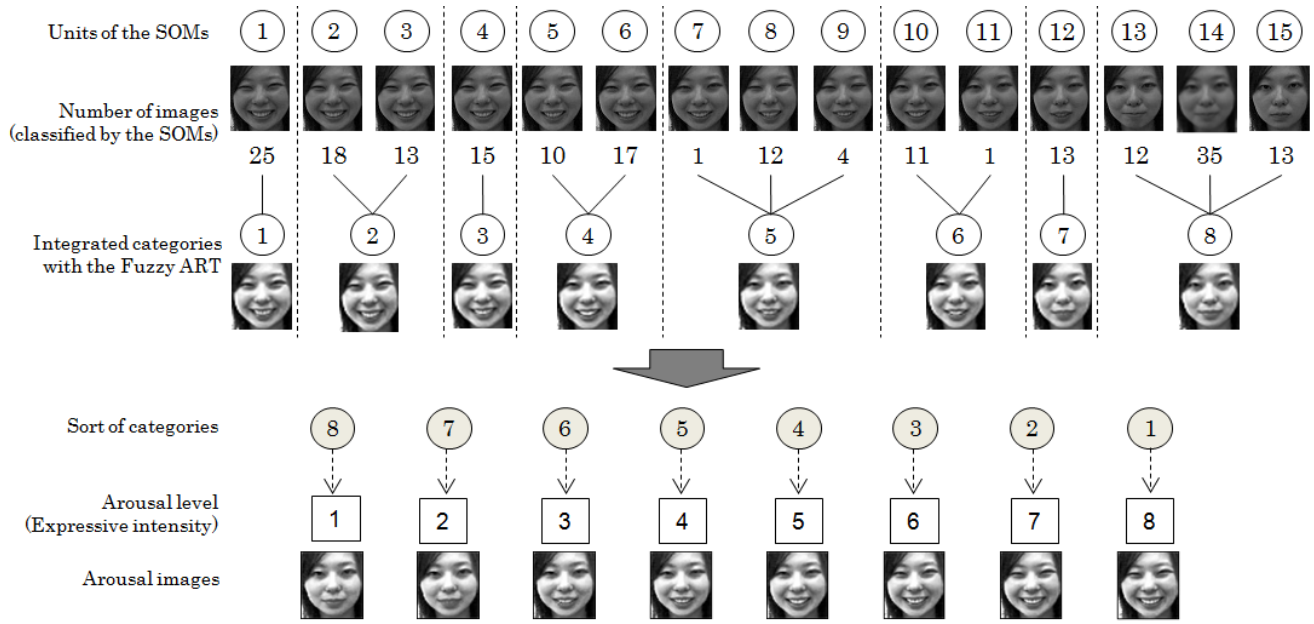


Figure 3. Expressive intensity.

we reduce noise and constrain the amount of information using time-series images decorated with Gabor wavelets and processing coarse graining. The period during which images were obtained was expanded from several weeks to several months. Although we took facial expression images in constant conditions, we were unable to constrain external factors completely, e.g., through lighting variations. Therefore, in the first step, brightness values are preprocessed with normalization of the histogram to the target images. In the next step, features are extracted using Gabor wavelet filtering. The information representation of Gabor wavelets that can emphasize an arbitrary feature with inner parameters shows the same characteristics of response selectivity in a receptive field. Gabor wavelets are functions that combine with a plane wave propagating to one direction and a Gaussian wave. We used the three directions of 0, 45, and 90 deg for selective responses for facial parts. At the final step, we applied down-sampling for noise reduction and data size compression. For this method, we set the initial template position to include facial parts for capturing facial images. We use template-matching methods to trace the region of interest of a face in real time. However, the trace results of the region of interest yield errors caused by body motion. These errors can be removed through down-sampling. The down-sampling window that we set is 10 × 10 pixels. The target images are compressed from 80 × 90 pixels to 8 × 9 pixels.

Facial expression processes differ among individuals. Therefore, Akamatsu described the adaptive learning mechanisms necessary for modification according to individual characteristic features of facial expressions. This study targets intentional facial expressions. We use SOMs [18] to extract topological changes of facial expressions and for normalization with compression in the direction of the temporal axis. After classification by SOMs, facial images are integrated using Fuzzy ART [19], which is an adaptive learning algorithm with stability and plasticity. In fact, SOMs perform unsupervised classification input data into a mapping space that is defined preliminarily. In contrast, Fuzzy ART performs unsupervised classification at a constant granularity that is controlled by the vigilance parameter. Therefore, using SOMs and Fuzzy ART together, time-series datasets showing changes over a long term are classified with a certain standard. Here, we used one-dimensional SOMs with 15 mapping units and set the vigilance parameter of Fuzzy ART to 0.90 through a preliminary experiment.

Figure 3 presents details of procedures for acquiring a time-series variation of expressive intensity. First, we use SOMs to learn the time-series images of facial expressions with down-sampling. The face images that show topological changes of facial expressions that are similar are classified into 15 mapping units of SOMs. Next, similar units among 15 mapping units of SOMs are integrated into the same category by Fuzzy ART. By sorting the facial expression categories integrated by Fuzzy ART from neutral facial expression to the maximum of facial expression, we obtain categories labeled as expressive intensities of facial expressions quantitatively.

V. MODEL OF STRESS ELEMENTS

A Bayesian network is a knowledge representation scheme dealing with probabilistic knowledge [20]. Its nodes and arcs mutually connect, forming a directed acyclic graph. Each node can be viewed as a domain variable that can take a set of discrete values or continuous value. An arc represents a probabilistic dependency between the parent node and the child node. We illustrate the graphical modeling approach using a real-world case study, such as modeling and inferring human psychological stress by integrating information from intentional facial expressions and four levels of expression intensity, three stress factors, and 18 stress attributions of SRS-18. A probabilistic psychological stress model based on the BNs is a suitable option to address the relation between facial expressions and human psychological stress.

Table I presents parameters representing the psychological state, which is the input of the stress element model, i.e., three stress factors and 18 stress elements. Table II shows the state values of three facial expressions (i.e., "happiness", "sadness", and "anger") and the stress response degree as stochastic variables for outputting occurrence probabilities. In the BNs, the state value of each variable, the conditional probability, and the graph structure are constructed by statistical learning using the previously obtained dataset. The constructed BNs determined the state value of the expression type as an output variable from the observed dataset. Then, it performed probabilistic inference for the parameters representing the psychological states of the input variables. Consequently, the probability distribution of each state value of the input variable is obtainable. The BNs might be assessed as stochastic parameters representing the mental state at that time from the occurrence probability distribution of intentional facial expressions. Therefore, using Bayesian networks, we were able to estimate the parameters determining the state of mind at that time and specific the type of facial expression easy to expose at a certain psychological state.

Using a program package of Bayesian Network Construction System (BayoNet) [21], the stress element models used for this study were constructed with the structure learning employing K2 algorithm [22] as a model search algorithm, Akaike Information Criterion (AIC) [23] as the model evaluation criterion. The details are explained below.

A. Definition of Variable Nodes

The stress model used in our experiment comprises 25 nodes. A stress element model was constructed from 18 stress elements, three stress factors, three facial expression intensities, and one stress response degree. The "depression and anxiety", "displeasure and anger", and "lassitude" of stress factors accommodate parent nodes for the six stress elements. The stress factors are parent nodes to the stress response degree node, which are the child nodes. We set relations manually between the parent and child of facial expression intensities and stress factors. We set stress factors and expression intensity respectively as parent and child nodes based on preconditions for psychological stress influence to facial expressions. Furthermore, we set directed links for stress elements as six nodes to each stress factor based on a precondition that stress elements trigger stress factors.

The 18 nodes of stress elements are assigned 0–3 points with four items: "Strongly no", "Yes a little", "Yes", and "Definitely yes". All stress factor nodes have four grades: Level 1 (weak), Level 2 (normal), Level 3 (slightly high), and Level 4 (high).

TABLE I. INPUT VARIABLES OF BNS

Stress factor	State	Stress element	State
Depression and anxiety	Level 1 (i.e., weak) Level 2 (i.e., normal) Level 3 (i.e., slightly high) Level 4 (i.e., high)	sad mood	3:Definitely yes 2:Yes 1:Yes a little 0:Strongly no
		worry	
		feel like crying	
		disheartened	
		being bored	
		want to comfort	
Displeasure and anger	Level 1 (i.e., weak) Level 2 (i.e., normal) Level 3 (i.e., slightly high) Level 4 (i.e., high)	quick-tempered	3:Definitely yes 2:Yes 1:Yes a little 0:Strongly no
		feel anger	
		lose one's cool	
		feel unhappy	
		be annoyed	
		feel frustrated	
Lassitude	Level 1 (i.e., weak) Level 2 (i.e., normal) Level 3 (i.e., slightly high) Level 4 (i.e., high)	have no confidence	3:Definitely yes 2:Yes 1:Yes a little 0:Strongly no
		consider bad things	
		not completed	
		want to be alone	
		can't focus	
		not patience	

TABLE II. OUTPUT VARIABLES OF BNS

Facial expression	Region of interest	State
Happiness	Entirety of face	1 – 15 (Expressive intensity)
	Upper part of face	
	Lower part of face	
Anger	Entirety of face	1 – 15 (Expressive intensity)
	Upper part of face	
	Lower part of face	
Sadness	Entirety of face	1- 15 (Expressive intensity)
	Upper part of face	
	Lower part of face	
Stress response degree		Level 1 (i.e., weak) Level 2 (i.e., normal) Level 3 (i.e., slightly high) Level 4 (i.e., high).

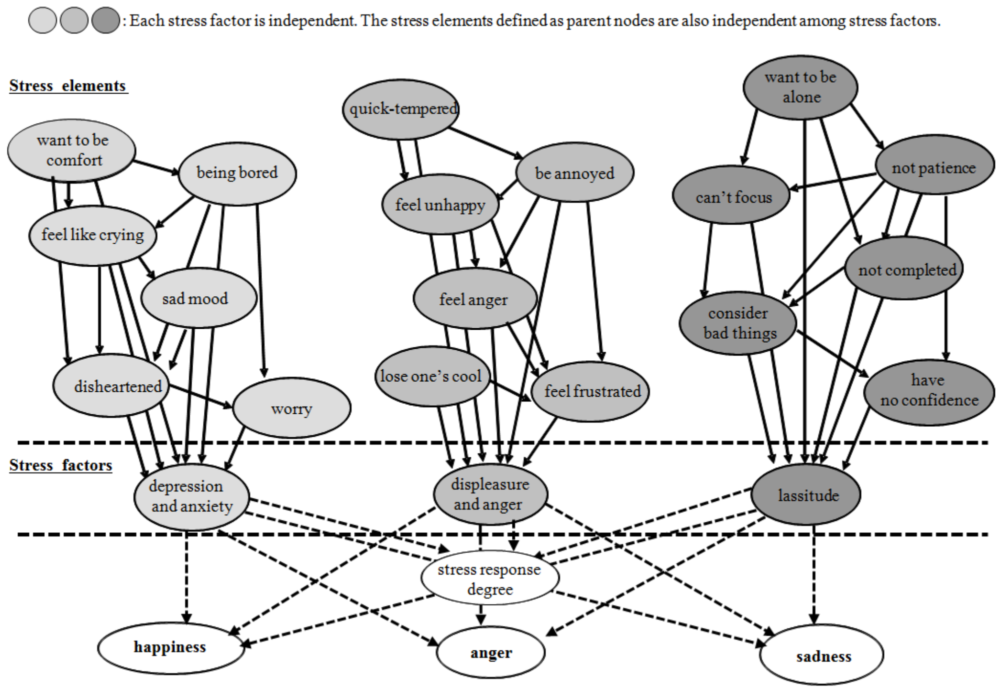


Figure 4. Stress elements model without constraints.

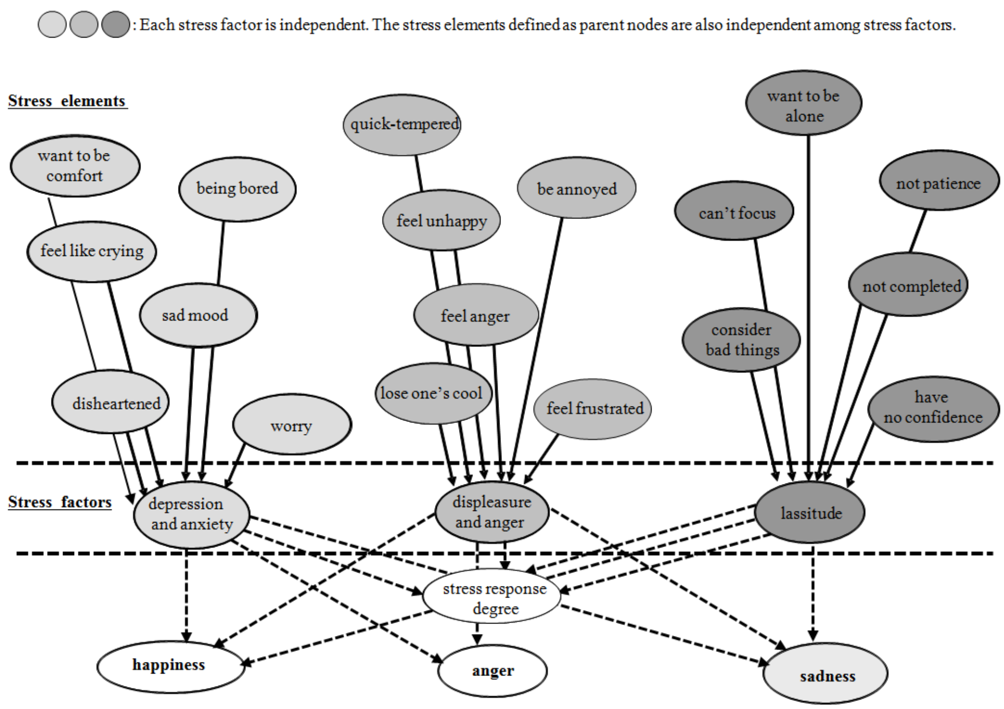


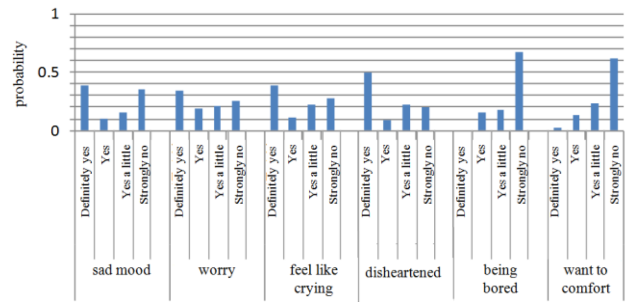
Figure 5. Stress elements model with constraints.

VI. ANALYSIS OF STRESS ELEMENT MODEL

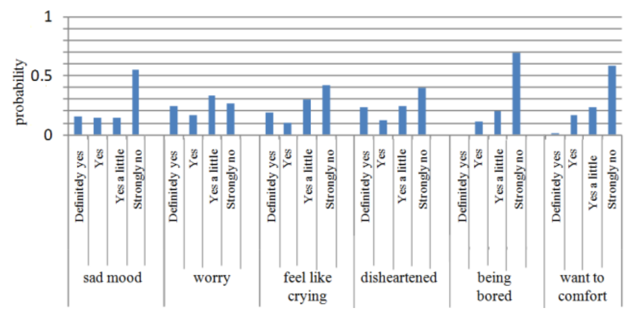
For the analysis described in this section, we constructed two models given certain constraints on different nodes of stress factors to obtain a single simple model for which effects of stress are noticeable. Using the selected model, we attempt to analyze the types of facial expressions that are readily influenced by stress. Subsequently, we shall analyze the stress factors and stress elements supporting them. To ascertain differences in stress susceptibility by gender, we compare the results of analysis of stress elements obtained for men with those obtained for women.

A. Model Construction

As a preliminary experiment, we constructed models of stress elements under two constraints: "with constraints, where each factor is independent"; and "without constraints, allowing relations among elements". The model of "without constraints" in Figure 4 is constructed with an optimal graph structure representing the correlation of multiple stages by connecting each stress element with an arc. However, the model of "with constraints" in Figure 5 shows a simple graph structure by which stress elements form directed links correspond to stress factors. As might be inferred from the contents of the preliminary experiment, no need exists to define an exact correlation between stress elements because a tendency is apparent by which the probability distributions of the stress levels and expressive intensities are similar, irrespective of the presence or absence of constraints. However, the probability distribution of the model without constraints is an important characteristic for the analysis of stress elements. In other words, although the stress elements that characterize the factor of "depression and anxiety" are not found in Figure 6(b), dominant changes appear in the probability distribution of "sad mood", "feel like crying" and "disheartened" as stress elements characterizing the factor of "depression and anxiety" in Figure 6(a). It is regarded as more effective when performing probabilistic inference.



(a) Without constraints



(b) With constraints

Figure 6. Probability distribution of stress elements.

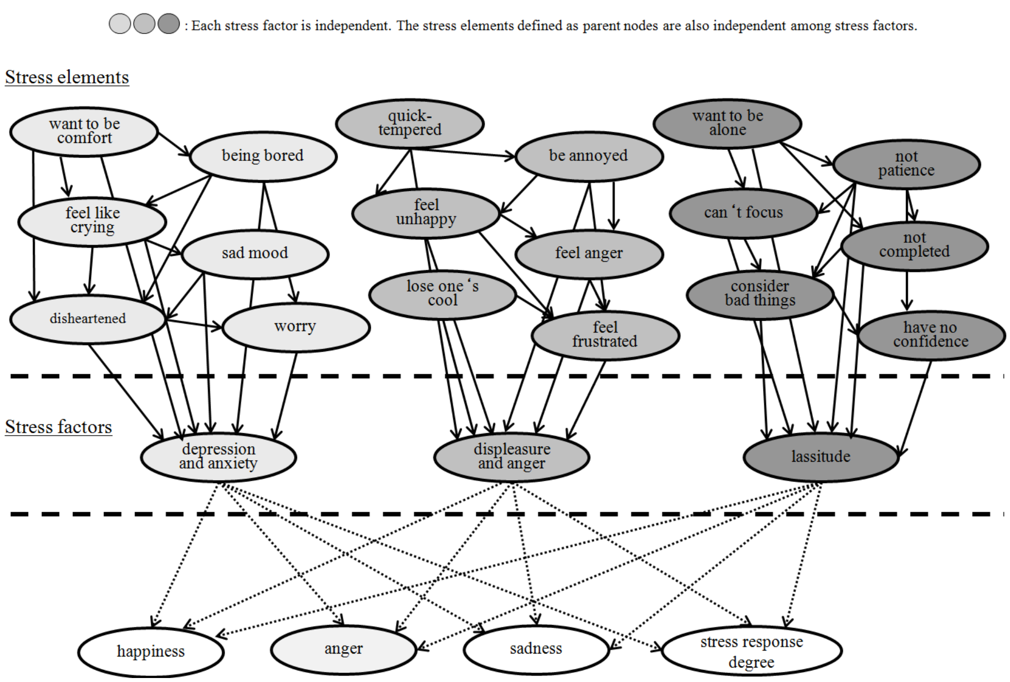


Figure 7. Stress elements model of male.

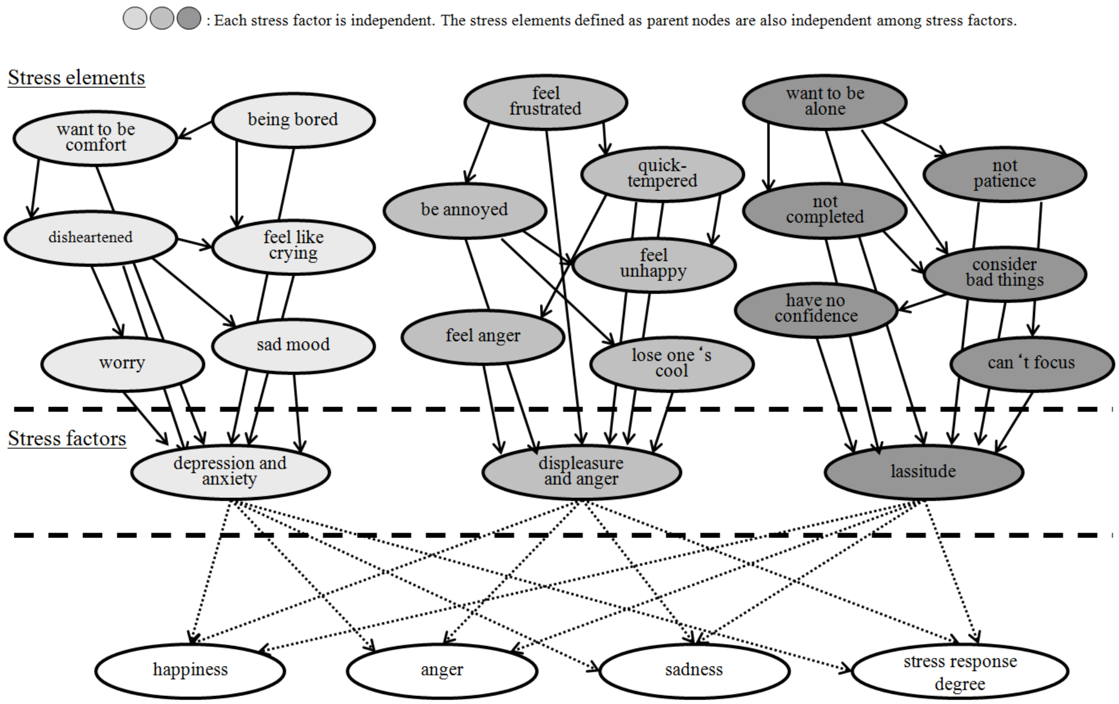


Figure 8. Stress elements model of female.

Therefore, for the following experiments, we use the stress element model without constraints, allowing their relation among elements.

B. Analytical Procedures

The stress element models of men and women are presented in Figure 7 and Figure 8. Each node in stress factors, such as "depression and anxiety", "displeasure and anger", and "lassitude", has directed links to six items of stress elements as parent nodes. The directed links signify that nodes connected with them are optimized for better inferential accuracy. Therefore, a strong mutual relation exists between nodes that are connected by directed links.

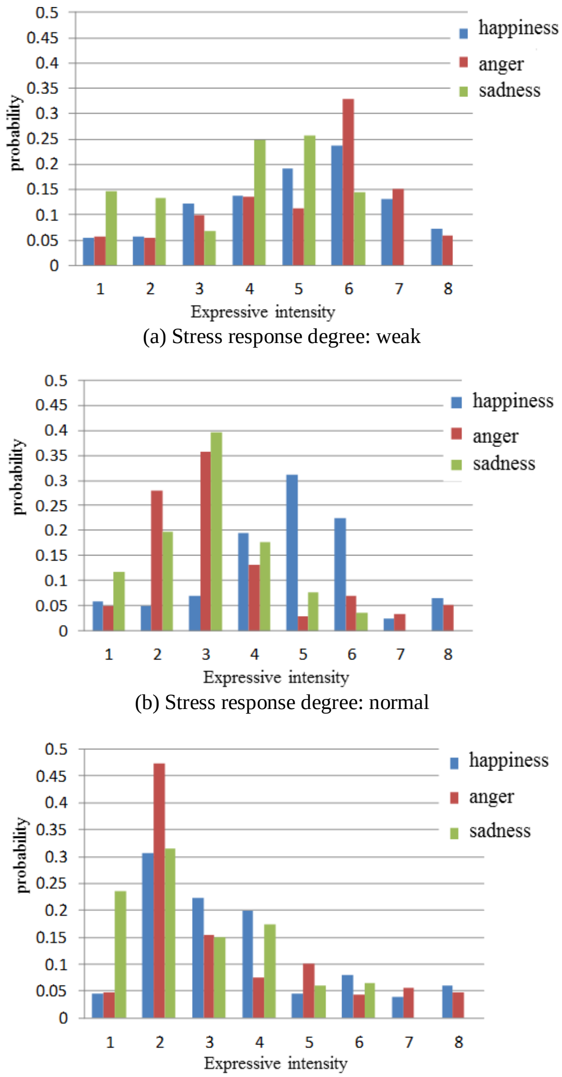
The analytical procedures of stress factors that affect the facial expressions are described in the following based on the stress element models. As the flow of the entire analysis, by giving evidence to the degree of stress response, and by comparing the probability distribution of the expressive intensities "happiness", "anger" and "sadness", we strive to identify facial expressions that are sensitive to stress. Additionally, we verify all stress elements in terms of whether they affect the expressive intensities of the facial expression.

First, we calculate the expressive intensities of three facial expressions by giving evidence to the stress response degree as "weak". Conducting stochastic reasoning based on the probability distribution related to each expressive intensity, the most sensitive stress that is likely to appear in any facial expression was determined. Next, we assessed the degree of stress responses of "slightly high" and "normal" using the same procedures. We specifically examine the probability distribution of expressive intensities in three facial expressions. Furthermore, even for stress elements corresponding to each stress factor, using the same procedures as stochastic reasoning, we identify the stress factors and elements that affect expressive intensities in facial expressions.

C. Male Model

Figure 9 presents a probability distribution of the expressive intensities corresponding to each stress response degree in the male model. Giving evidence to the stress response degree as "weak", the probability value was also larger as the expressive intensity increases. For the case in which the stress response degree is "normal" compared to "weak", the probability value is greater when the expressive intensity is small. Moreover, in the case of "slightly high", probability values tend to be large in all three facial expressions, when expressive intensities are small. Estimating the expressive intensity corresponding to stress response degree is particularly difficult for facial expressions of "anger" and "sadness" because it is small in the state of "normal" stress.

Therefore, we will strive to conduct analyses particularly addressing the "happiness" facial expression, for which the probability value of expressive intensity is changing related to the stress response degree. To analyze the stress factors and stress elements that support them on the "happiness" facial expression, by giving evidence sequentially from "Level 1" to "Level 4" for total stress levels, we identify the



(a) Stress response degree: weak

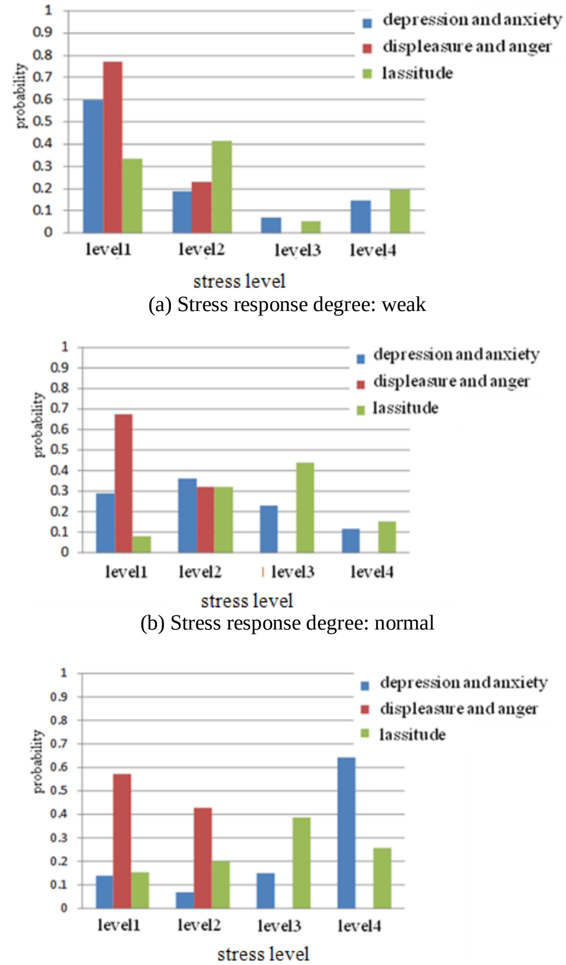
(b) Stress response degree: normal

(c) Stress response degree: slightly high

Figure 9. Probability distribution of the expressive intensities corresponding to each stress response degree in male model.

stress factors affecting facial expressions from their probability distributions of expressive intensities. Furthermore, we examine the link structure of the stress elements related to the stress factor that has been identified.

Figure 10 depicts a probability distribution of the stress level in each stress factor. As the stress response degree becomes higher, the level of the stress factor "depression and anxiety" indicates a higher value. This phenomenon appears most significantly on the estimated value of the probability distribution. However, for the stress factors of "lassitude" and "displeasure and anger", characteristic changes are not observed in the estimated value of the probability distributions at respective stress levels.



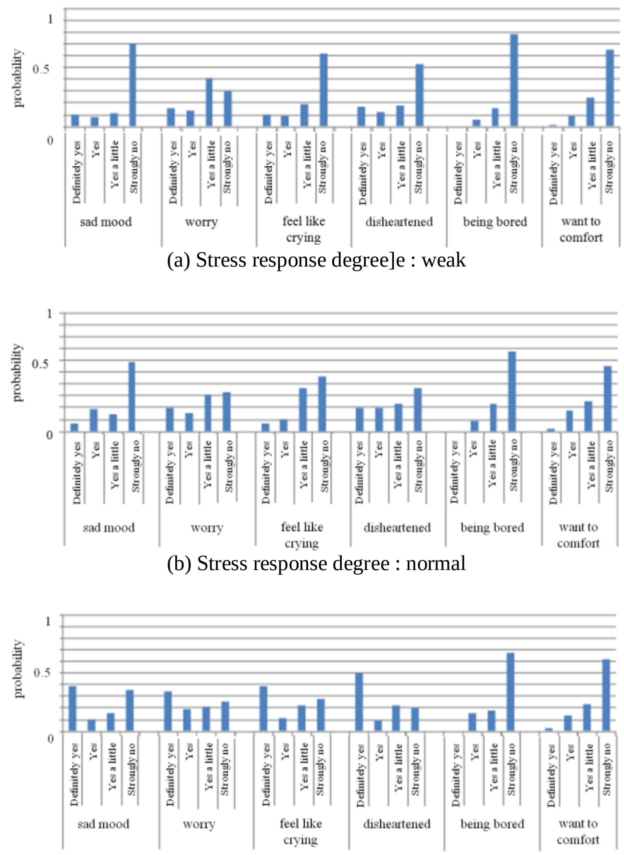
(a) Stress response degree: weak

(b) Stress response degree: normal

(c) Stress response degree: slightly high

Figure 10. Probability distribution of the stress levels with emphasis on the facial expression of "happiness".

Therefore, in the male model, we consider that the factor of "depression and anxiety" affects the facial expressions of "happiness" as a stress factor. Then, targeting the six stress elements characterizing the factors of "depression and anxiety", we attempt to identify the stress factors for supporting the relevant factor. We set evidence for the stress response degrees of "normal", "weak", and "slightly high". Figure 11 portrays the probability distribution of stress elements for each stress level. For "normal" and "weak" as stress response degrees, the highest probability value of "Strongly no" denying the stress elements was identified. Other probability values were less than 0.3. For "slightly high" as a stress response degree, stress elements of "sad mood", "feel like crying", and "disheartened" showed high probability values together for support of the cause of "Definitely yes".



(a) Stress response degree]e : weak

(b) Stress response degree : normal

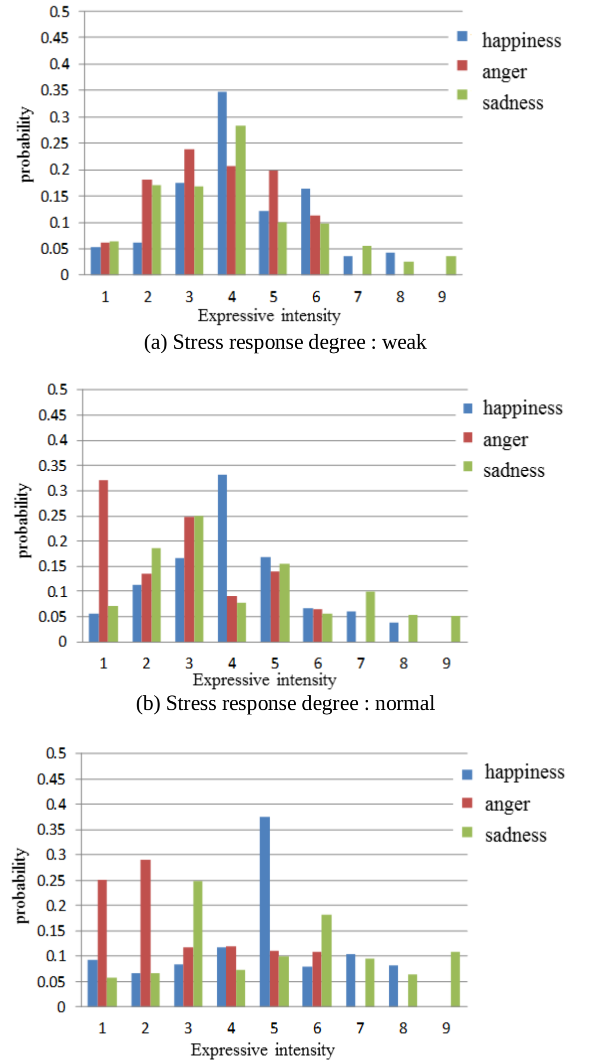
(c) Stress response degree : slightly high

Figure 11. Probability distributions of the stress elements characterizing the factors of "depression and anxiety" in male model.

D. Female Model

Using the same procedure as that used for men, we analyzed the relations among stress factors, stress elements, and expressive intensities of three facial expressions for women. In the female model, a marked change was recognized in the probability distribution of expressive intensity of "sadness", as presented in Figure 12.

Figure 13 presents a probability distribution of stress levels with emphasis on the facial expression of "sadness" in each stress factor. As might be understood from the contents of Figure 13, particularly addressing the probability distribution of the factors of "lassitude" and "depression and anxiety", a considerable change is apparent with the difference of stress response degree, i.e., "weak", "normal", and "slightly high". The probability distributions of the stress elements characterizing the factor of "depression and anxiety" are presented in Figure 14. As a stress element giving influence to the factor of "depression and anxiety", the influence of "disheartened" exists to a slight degree. However, no distinctive element to support the factor of "lassitude" is found anywhere because the probability



(a) Stress response degree : weak

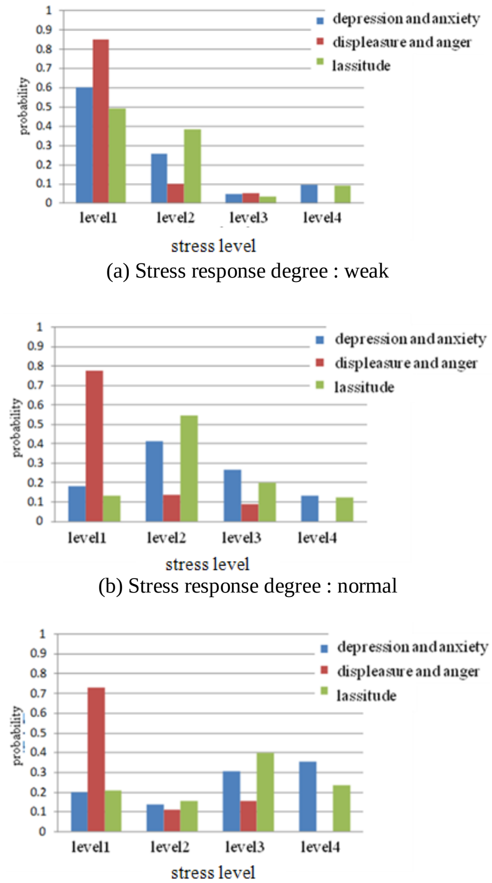
(b) Stress response degree : normal

(c) Stress response degree : slightly high

Figure 12. Probability distribution of expressive intensities corresponding to each stress response degree in female model.

distribution shows a similar tendency to that of the change of the degree of stress response.

Based on the experimentally obtained results presented above, we conduct an examination from the perspective of stress factors and stress elements giving influence to them, specifically examining the relation between psychological stress and three facial expressions for men and women. Some facial expressions appear easily, but others are difficult to assess in terms of psychological stress. In the male model, facial expressions of "happiness" show marked changes attributable to differences in the stress response degree, but characteristics of the probability distribution of expressive intensities are similar in facial expressions of "sadness" and "anger". Expressive intensities become slight with the increase of stress response degree as an overall trend. In the female model, a change was observed in the

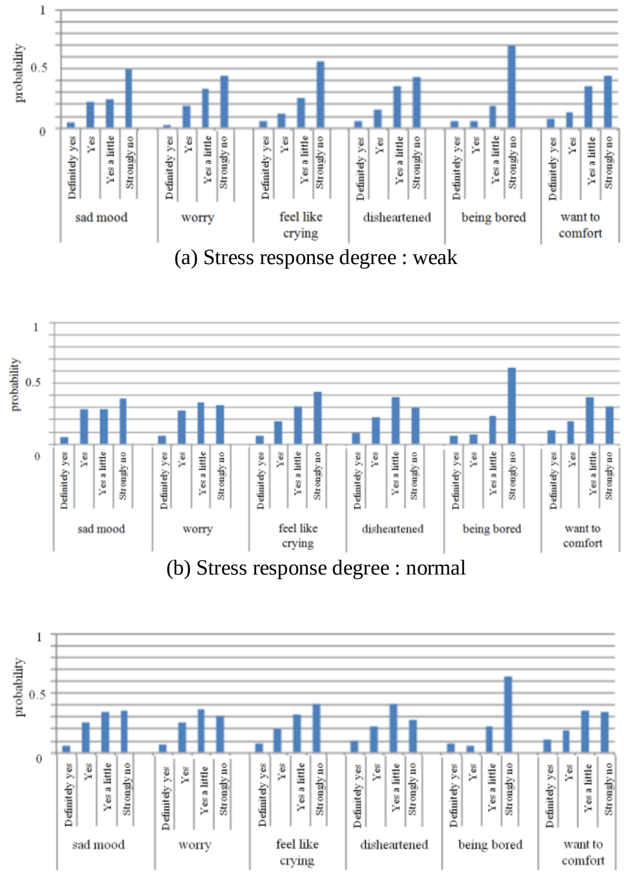


(a) Stress response degree : weak

(b) Stress response degree : normal

(c) Stress response degree : slightly high

Figure 13. Probability distribution of stress levels with emphasis on the facial expression of "sadness".



(a) Stress response degree : weak

(b) Stress response degree : normal

(c) Stress response degree : slightly high

Figure 14. Probability distributions of the stress elements characterizing the factors of "depression and anxiety" in female model.

characteristics of the probability distribution of expressive intensities, only the facial expression of "sadness", by setting evidence to the stress response degree as "slightly high".

Therefore, we inferred that the influence of psychological stress appears easily in the expression of "happiness" for men and in the expression of "sadness" for women. In addition, the factor of "depression and anxiety" as a stress factor influences the facial expressions of "happiness". Then, as stress elements which support it, three items exist for men: "sad mood", "feel like crying", and "disheartened". Although significant changes were observed in the probability distribution of the factors of "lassitude" and "depression and anxiety", the female model did not engender specific stress elements to support those stress factors.

VII. Stress Factors and Effect of Face Region

In this section, we first classify the state (slightly high) of levels 3–4 and the state (weak) of level 1 for which each stress factor holds the state of "Level 4" from "Level 1". Next, by probabilistic reasoning of giving evidence in these two states, we strive to identify the face region (upper part of the face, lower part of the face) in which psychological stress effects readily appear. For this experiment, we use the model of stress elements for all subjects: the 10 university student subjects comprise 5 men and 5 women. The stress element model of all subjects is presented in Figure 15. This model is a graph structure consisting of 28 nodes: 18 nodes corresponding to the stress elements, 3 nodes corresponding to the stress factors, one node corresponding to the stress response degree, and 6 nodes corresponding to the expressive intensities appearing in the lower part and upper part of the face on three facial expressions.

A. *Factor of 'Depression and Anxiety'*

Figure 16 presents expressive intensities of parts of the face, where we set evidence to the state (slightly high) of levels 3–4 and the state (weak) of level 1, assessing the factor of "depression and anxiety". Estimation results of stress levels and expressive intensities are presented in Figure 16(a). The relation between types of facial expression and the differences of expressive intensity are presented in Figure 16(b). These two figures are summaries

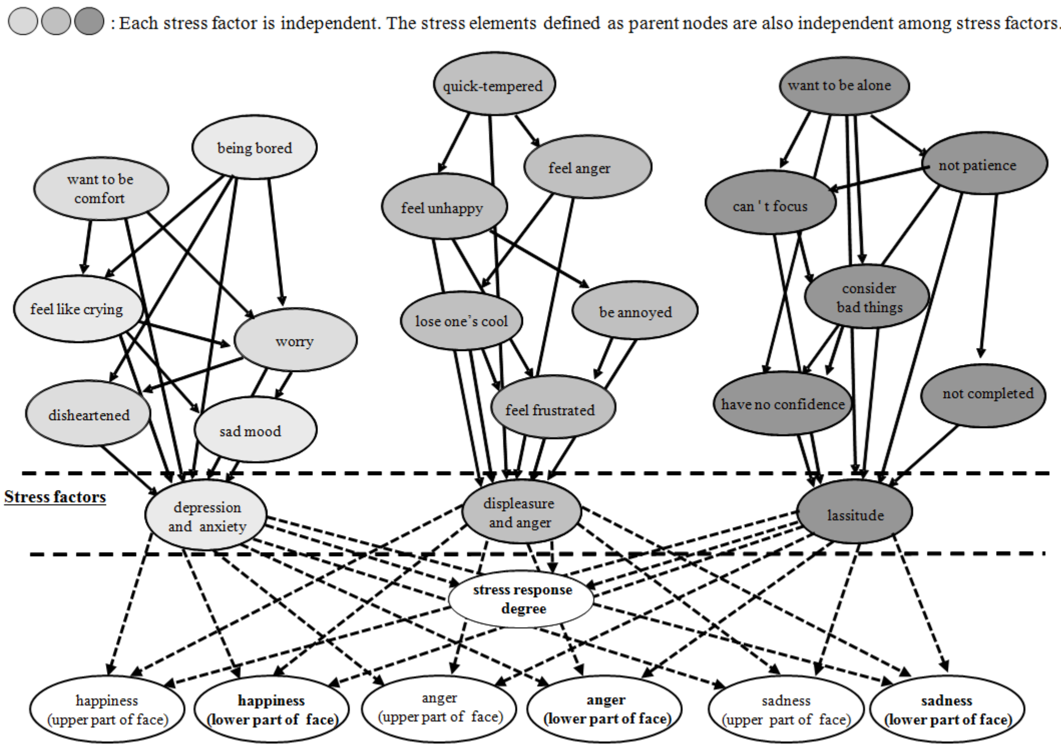


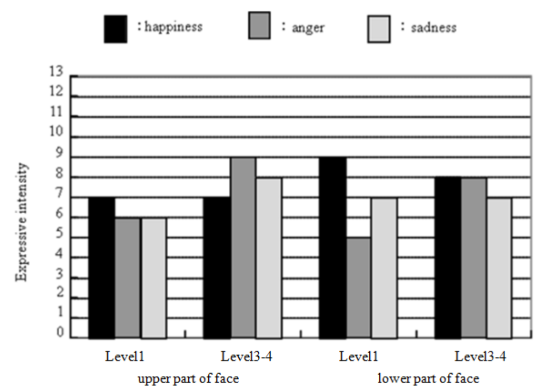
Figure 15. Stress elements model of all subjects.

for the respective face regions. The vertical axes in the figures respectively show the expressive intensity and the difference of expressive intensity. It is noteworthy that the difference of expressive intensity shows the absolute value of the difference between the expressive intensity levels "3-4" and "level 1" in respective states.

Specifically, assessing the differences of expressive intensity in "happiness", "anger", and "sadness", the respective values of the upper part of the face are 0, 3, and 2. In contrast, the respective values of the lower part of the face are 1, 3, and 0. In the case in which the stress factor of "depression and anxiety" acts significantly, large values have been identified for the upper and the lower part of the face at expressing "anger". Therefore, the influence of "depression and anxiety" readily appears at expressing 'anger'. Additionally, we infer that the influence affects the entire face region. These analytical results are consistent with the contents of the previous study described in [18], i.e., the emotional states of mind stimulating "anger" and "depression" are similar.

B. *Factor of 'Displeasure and Anger'*

Figure 17 presents the expressive intensities of each face region based on the stress factors of "displeasure and anger", as presented in the preceding section. Specifically examining the differences in expressive intensity in "happiness", "anger", and "sadness", the respective values of the upper part of the face were 2, 1, and 4. In contrast, the



(a) Estimation of stress levels

(b) Difference of expressive intensity each face part

Figure 16. Expressive intensities of parts of the face.

respective values of the lower part of the face are 0, 1, and 2. Accordingly, we consider that the following analysis is reasonable, i.e., the influence of "displeasure and anger" readily appears at the upper part of the face of expressing "anger".

In addition, because we are conducting the operation of "glaring" to intimidate an opponent expressing "anger", this analytical result matches a case study showing changes that occur during that process, such as "eyebrows down" or "upper eyelid is raised". Consequently, the effect readily appears strongly in the upper part of the face of the facial expression "anger", for the case in which the stress factor of "displeasure and anger" is readily apparent.

C. *Factor of 'Lassitude'*

Figure 18 exhibits expressive intensities of respective face regions based on the stress factor of "lassitude". Specifically examining the differences of expressive intensity in "happiness", "anger", and "sadness", the respective values of the upper part of the face are 5, 3, and 2. In contrast, the respective values of the lower part of the face are 1, 3, and 4. Accordingly, we regard the following analysis as reasonable: the influence of "lassitude" readily appears at the upper part of the face expressing "happiness", and the lower part of the face expressing "sadness".

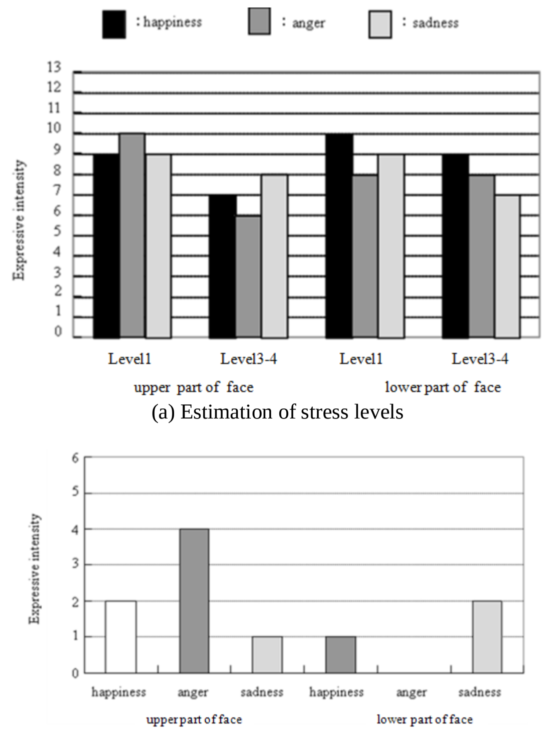
In general, changes in facial expressions are poor during the state of "lassitude". Therefore, a tendency to fall "expressionless" appears to be confirmed. However, results indicate that the influence appears strongly in the lower part of the face for the expression of "sadness" and in the upper part of the face of the expression 'happiness' in this analysis. For this study, we adopted an experimental protocol in which all subjects intentionally express three facial expressions of "happiness", "sadness", and "anger", even when they are in the state of "lassitude". Therefore, these reasoning results reflect the characteristics of datasets based on the experimental protocol. Although the factor of "lassitude" contributes significantly, results show that the effect readily appears in the lower part of the face of the expression "sadness" and in the upper part of the face of the expression "happiness" for intentional facial expressions.

VIII. CONCLUSION AND FUTURE WORK

This study, which analyzed stress factors and elements of psychological stress on intentional facial expressions using BNs, was conducted to identify the types of facial expressions and facial parts which readily manifest the influence of psychological stress. Our evaluation experiment used stochastic reasoning to build stress element models for male and female subjects, providing evidence for the stress response degree and stress factors.

Results revealed the following points.

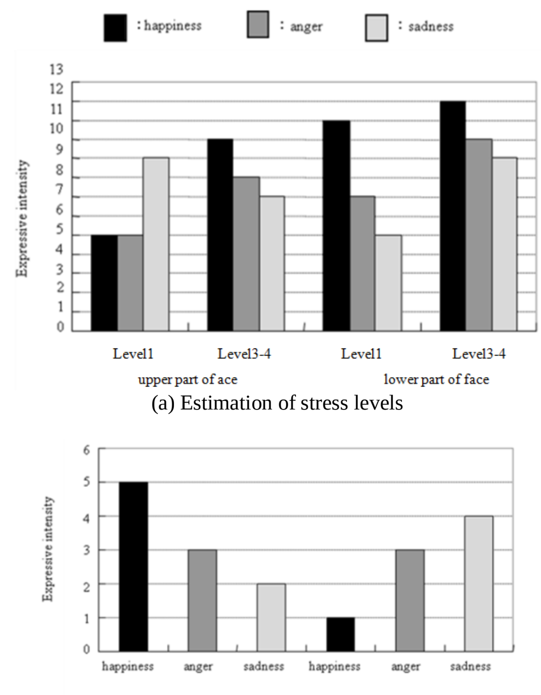
1) When building a stress element model, a model of "without constraints" that allows relations among stress elements is more beneficial for analysis of probabilistic reasoning results than a model of "with constraints".



(a) Estimation of stress levels

(b) Difference of expressive intensity each face part

Figure 17. Expressive intensities of each face region based on the stress factors of "displeasure and anger".



(a) Estimation of stress levels

(b) Difference of expressive intensity each face part

Figure 18. Expressive intensities of respective face regions based on the stress factor of "lassitude".

2) The "depression and anxiety" factor affects the facial expression of "happiness" in men.
3) The "depression and anxiety" and "lassitude" factors affect the facial expressions of "sadness" in women.
4) The influences of "depression and anxiety" readily appear when expressing "anger". They affect the entire face.
5) The influence of "displeasure and anger" readily appears in the upper part of the face when expressing "anger".
6) The influence of "lassitude" strongly appears in the lower part of the face of the expression of "sadness", in the upper part of the face of the expression of "happiness".

We will estimate models of stress elements by increasing the number of subjects and the image capture duration. Furthermore, we will improve our method to address both intentional facial expressions and natural expressions that are exposed unconsciously.

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References

[1] K. Sato, H. Otsu, H. Madokoro, and S. Kadowaki, “Analysis of psychological stress factors and facial parts effect on intentional facial expressions,” Proceedings of The Third International Conference on Ambient Computing, Applications, Services and Technologies (AMBIENT2013), pp. 7-16, Oct. 2013.

[2] T. Yata, H. Sannohe, M. Nakasako, and M. Tao, “How to cope with stress,” Yuhikaku, 1993.

[3] S. Akamatsu, “Recognition of facial expressions by human and computer [I]: facial expressions in communications and their automatic analysis by computer,” The Journal of the Institute of Electronics, Information, and Communication Engineers, vol. 85, no. 9, pp. 680-685, Sep. 2002.

[4] H. Shimomura, K. Kanamori, J. Nishimaki, and K. Shiba, “Usefulness of salivary amylase and cortisol measurement as stress markers at educational sites,” ISSN, vol. 33, no. 3, pp. 247-254, 2010.

[5] N. Takai, M. Yamaguchi, T. Aragaki, K. Eto, K. Uchihashi, and Y. Nishikawa, “Effect of psychological stress on the salivary cortisol and amylase levels in healthy young adults,” Arch Oral Biol., vol. 49, no. 12, pp. 963-968, 2004.

[6] Medicore Co. Ltd., Body Checker (Cardio Monitor), http://www.medi-core.com/ [retrieved: June, 2014]

[7] M. Malik, “Heart rate variability: standards of measurement, physiological interpretation, and clinical use,” European Heart Journal, vol. 17, pp. 354-381, 1996.

[8] Brain Function Research Center, Alphatec-IV, http : //www.alphacom.co.jp/ [retrieved: June, 2014]

[9] R. S. Lewis, N. Y. Weekes, and T. H. Wang, “The effect of a naturalistic stressor on frontal EEG asymmetry,” Biological Psychology, vol. 78, pp. 239-247, 2007.

[10] I. Akirav and M. Maroun, “The role of the medial prefrontal cortex–amygdala circuit in stress effects on the extinction of fear,” Neural Plast. 2007; 2007: 30873. Published online 2007 Jan. doi: 10.1155/2007/30837.

[11] D.M. McNair, J.W.P. Heuchert, and E. Shillony, Research with the Profile of Mood States (POMS), Toronto, Canada: Multi-Health Systems, 1964-2001.

[12] Comprehensive Support Project, ISTRESS Scale Guidebook, Jitsumu Kyouiku, 2004.

[13] S. Suzuki, “Stress Response Scale-18,” Kokoronet, Jul. 2007.

[14] Mechanical Social Systems Foundation, “Surveillance Study to Security Precaution of Stress Instrumentation Technology on Possible Application,” 2004.

[15] H. Madokoro, K. Sato, and S. Kadowaki “Facial expression spatial charts for representing time-series changes of facial expressions,” Japan Society for Fuzzy Theory, vol. 23, no. 2, pp. 157-169, 2011.

[16] P. Ekman, “Emotions Revealed: Understanding Faces and Feelings,” Kawade Shobo Shinsha, 2004.

[17] J.A. Russell and M. Bullock, “Multidimensional scaling of emotional facial expressions: similarity from preschoolers to adults,” Journal of Personality and Social Psychology, vol. 48, pp. 1290-1298, 1985.

[18] T. Kohonen, Self-organizing maps, Springer Series in Information Sciences, 1995.

[19] G.A. Carpenter, S. Grossberg, and D.B. Rosen, “Fuzzy ART: fast stable learning and categorization of analog patterns by an adaptive resonance system,” Neural Networks, vol. 4, pp. 759-771, 1991.

[20] Y. Motomura, “Probabilistic reasoning algorithms and their experiments in bayesian network,” IEICE, pp. 157-162, 2004.

[21] Y. Motomura, “Bayesian network software bayonet,” Journal of the Society of Instrument and Control Engineers, vol. 42, no. 8, pp. 693-694, 2003.

[22] G. Cooper and E. Herskovits, “A Bayesian method for the induction of probabilistic networks from data,” Machine Learning, no. 9, pp. 309-347, 1992.

[23] H. Akaike, “Information theory and an extension of the maximum likelihood principle,” Proceedings of the Second International Symposium on Information Theory, pp. 267-281, 1973.