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A biologically inspired model of emotion eliciting from visual stimuli

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ABSTRACT

Several emotion eliciting models have been proposed in the literature, however most of them are still artificial models which ignore the biological basis. We propose an emotion (without awareness) eliciting model from visual stimuli, which is inspired by biology: we describe an emotion eliciting process that follows the circuits of emotion in the brain derived through the results of neuroscience and the three major modules in the process, visual perception, emotion-eliciting region and emotional valence elicited by the region, are all supported by biology research. In our work, visual perception works with visual stimuli from coarse to the finer level according to human visual system. The elicited emotion in coarse level is also capable of affecting the emotion valence in the finer level. Based on psychophysical research, the emotion-eliciting region is selected out through color preference. The emotion is elicited by the emotion-eliciting region rather than overall visual context, which has been first introduced to computational modeling of emotion eliciting from image stimuli. The emotional valence elicited by the region is calculated on coarseness and directionality by comparing with stored image representations. In the experiments, two types of visual stimuli are considered: (1) natural scenes stimuli and (2) natural scenes and mutilation scenes stimuli. We compare the performance of our model with International Affective Picture System (IAPS), a large set of emotionally evocative color photographs that includes pleasure and arousal ratings made by men and women. Experimental results show that our model can generate human-like emotion based on natural scenes stimuli and obtain the positive or negative emotion as people feel on natural scenes and mutilation scenes stimuli.

1. Introduction

According to neuroscience, psychology and cognitive science, emotions, as the basic components of intelligence [1], impact our attention [2], perception [3], decision-making [4], behavior [5] and interactions [5,6]. In recent years, emotion is treated as a new research target of intelligence by information science scholars. There are two channels in human emotion: one transmits explicit information, such as facial expression and gesture; the other transmits implicit information, such as pleasure and arousal. However, studies in the field of emotional intelligence are mostly oriented towards the recognition of emotions in terms of visual or physical information [7,8]. The other research area involved in emotion eliciting model is to understand the emotional causes [9–11], which is the basic problem of emotional intelligence. To understand one's implicit emotion, it is reasonable to propose an emotion eliciting model based on the biological results.

In neuroscience, greater activation can be observed in amygdala, medial prefrontal cortex, orbitofrontal cortex and basal ganglia for emotional imagery than for neutral imagery [2,12–14]. Emotional experience is known to have two components: automatic emotion (activated without intention or awareness) and attended emotion (activated with intention or awareness). Automatic emotions activate subcortical regions, particularly the amygdala, then automatically process basic threat-related stimuli [5,15]. For example, surprise attack subconsciously facilitates reflexive actions. The stimuli are transmitted to the lateral amygdala and thence to the accessory basal amygdala, which connects with ventromedial hypothalamus, premammillary nucleus, ventral periaqueductal gray circuitry [16]. Attended emotions activate fronto-parietal area involved in aware processing, by providing a global workspace or by amplifying stimuli representations in other neural regions to convey these stimuli to awareness [17,18]. Williams et al. [19] show that amygdala activity while coming across fearful faces is enhanced even when attention is diverted elsewhere. The study shows amygdala can be active without awareness. Lesion studies [20,21] also support the important role of the amygdala in emotion eliciting and propose the independence of emotional processing from attention mechanisms.

From the perspective of psychology, emotions have mainly been researched from two fundamental viewpoints. One is that emotions are discrete and fundamentally have different categories

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in which a few selected emotions are basic or primary [22]. Ekman supports this viewpoint and he points out that anger, disgust, fear, joy, sorrow, and surprise are the basic emotions [22]. And the other viewpoint is that emotions can be characterized on dimensional basis, in which emotions are mental states of positive or negative and some arousal-based content [2,23–25]. Positive emotion reflects instances of happiness, interest, love and hope. Negative emotion reflects anger, contempt, disgust, disinterest, fear and sadness. We use the latter viewpoint in our model.

In recent years, the emotion based on appraisal theory has been considered in biological research. Appraisal theory develops a catalogue of human emotions and seeks to provide a computational account of the appraisals that lead one emotion to be evoked by events, agents and objects [26]. Sloman [27] proposes a three-level view of central processes: (1) Reactive: producing immediate actions; (2) Deliberative: selecting a preferred option after comparing possible predictions; (3) Meta-management: allowing internal processes to be monitored. Sander et al. [11] propose an appraisal-based emotion theory, namely Component Process Model, which is particularly suited to modeling with the help of artificial neural network approaches. However, such theories typically lack the necessary detail of stimuli to base a model.

As vision is one of the most important sensory modality in human experience, emotion elicited from visual stimuli has been focused by recent studies. Hess and Polt [28] propose that the pupils dilate for positive cues and constrict for negative cues. There are some features of imagery affecting human's emotions, such as color, texture, etc. Ou et al. [29] understand human emotion in response to seeing colors and colored objects and they call it color emotion. Lucassen et al. [30] conduct an experiment to measure and model how these color emotions change when texture is added to the color samples. However, Codispoti et al. [31] compare the late positive potentials to color versus grayscale pictures, and it is concluded that there is no effect on the affective modulation of the late positive potentials by removing color information. Their findings imply that the recognition of the emotional content of scenes dose not critically rely on color information. But color could facilitate scene segmentation. On the other hand, emotion states also influence vision. Srinivasan et al. [32] investigate the effects of global–local processing on the recognition of distractor faces with emotional expressions. They find that global processing correlated to happy faces and local processing correlated to sad faces. The result is consistent with Fredrickson's broaden-and-build theory [33] that positive emotions affect broad scope of attention.

A great deal of research has been conducted on the emotion eliciting from visual information, but very little work has been done to combine both emotion eliciting model and biological mechanisms. Yanulevskaya et al. [34] propose an emotion categorization system using holistic features from image statistics. The system is an artificial system which ignores interaction between visual perception and emotion. In order to overcome such problem, Zhang et al. [35] propose an autonomous emotion development system using human-like visual senses. However, the visual perception lacks of biological basis and the emotion is elicited by overall visual context in the system. To improve the performance of emotion eliciting model, Shin et al. [36] focus on textile image with annotation. Lee et al. [37] evaluate an emotional response to color images with their descriptors. However, the methods with descriptors [36,37] are largely dependent on manual or automated methods, which consume a lot of processing time. In this paper, we propose a biologically inspired emotion eliciting model without any annotation from visual stimuli. The proposed model based on biological mechanisms has a good performance compared with human behavioral responses contained in IAPS. Therefore, the present goal is to develop a model to mimic eliciting emotion from visual stimuli based on biological mechanisms and the main contributions of this work can be summarized as:

- We introduce a new general framework for emotion eliciting from visual stimuli, which is motivated by biology.
- We introduce a new method in computational modeling of emotion eliciting. In the proposed model, emotion is elicited by the emotion-eliciting region rather than overall visual context, which is first introduced to computational model. This method has improved the performance of emotion eliciting model.
- We propose a new process in emotion eliciting from visual stimuli. The three main modules in the process are based on biology. The experiments show that the proposed emotion eliciting model is promising compared with human behavioral responses contained in IAPS.

The remainder of this paper is organized as follows. In Section 2, the emotion-eliciting region algorithm and eliciting emotion valence algorithm according to the biological framework are proposed. The experimental results are shown in Section 3, with discussions and final conclusion presented in Section 4.

2. Methods

This section describes the process from visual image to eliciting automatic emotion according to the biological evidence of emotion circuit and the modules in the circuit. There are three major modules in the process: visual perception, selecting emotion-eliciting region and emotional valence elicited by the region.

The perception of visual stimuli is a process from coarse to fine. The emotion varies in the coarse-to-fine processing and the emotion in the coarse level also affects the perception in the finer level. It can ignore some unimportant regions of emotion to select the emotion-eliciting region. And emotion valence is elicited by the emotion-eliciting region.

2.1. The biological roots of emotion

The proposed emotion eliciting model from visual information is based on the results of neuroscience and psychology research. The overall structure, the main modules and the connections of our model are inspired by biology: (1) the circuits of the emotion eliciting model follow the interaction of the amygdala with cortical areas in the brain; (2) the construction of main modules in our model is based on the biological rules of (a) interaction between visual perception and emotion, (b) emotion elicited by the main region of interest in a scene, and (c) the specific methods to elicit emotion. The emotion eliciting model related to biological rules is shown in Fig. 1.

2.1.1. Biological rules of the circuits of the emotion eliciting model

Research on the neurobiology of automatic emotion yields an understanding of interacting brain structures and neural mechanisms from external stimulus. External stimulus elicit both fast elicitation of emotion and more refined emotion control based on high-level sensory representations and the stimuli are transmitted to behavioral control columns which belong to hypothalamic subsystems [12,14,16] that have developed in evolution to specifically control different motivated behaviors. The prefrontal cortex sends distinct projections to several regions of amygdala [5,12,16], connecting with elaborate cognitive functions to regulate the amygdala's roles in emotion [5,38,39]. The amygdala can influence cortical areas from proprioceptive, visceral or hormonal signals [38,39].