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Could linear model bridge the gap between low-level statistical features and aesthetic emotions of visual textures?

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ABSTRACT

Aesthetic perceptions are common in everyday life, even though we are not aware of these natural behavior and ability. The exploration of the processing pathways in human aesthetic perception of visual textures by modeling is vital and valuable in important domains such as product design and architecture. After conducting semantic differential rating experiments, we model the relationship between low-level texture features and aesthetic properties involved in human aesthetic texture perception. In this paper, we use multiple linear regression models to bridge the gap between computation texture features and aesthetic emotions that are more interpretable and clearer in structure than artificial neural network models. In feature extraction stage, four different categories of low level features are used to objectively represent the characteristics of visual textures. To reduce the information redundancy of the feature set and the complexity of the prediction model, the dimensionality reduction of the extracted feature set using stochastic neighbor embedding is implanted. In psychological experiment stage, the semantic differential rating experiment is conducted to collect the aesthetic perceptions of selected texture stimuli from participants, and then the aesthetic properties are assigned to three different model layers based on the neural mechanisms of aesthetic perception. Before model building, an evaluation of the presentation ability of feature subsets is firstly carried out to investigate whether there is a potential relationship between 8 high level aesthetic properties and the feature set including 106 texture features. Next, we describe the generation of a multiple linear regression model for aesthetic prediction by taking a reduced feature set as dependent variables. Experimental results indicate that the hierarchical feed-forward layer model of aesthetic texture perception proposed in our research can link computational texture features with aesthetic texture properties quite well.

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1. Introduction

We all know that stepping carelessly onto a wet marble floor might cause us to slip. The same way we know that running on grass in the park is safe; even if we fall we are unlikely to get hurt. Although we may not be aware of it, textures provide us with information that triggers certain emotional qualities and expectations [1]. Even though the concept of texture is not clearly defined and generally accepted in academic fields, texture is ubiquitous in our daily lives. In the ancient world, people have known that visual texture not only helps us to distinguish similar things but conveys aesthetic information. So, in the areas such as art and vision design, painting, packaging and architecture, the surface texture will be set as one of the vital factors and thus should be chosen carefully [2]. However, the related researches just have been carried out recently, which can be divided into two strategies. One is texture semantics analysis, the other is neuroaesthetics research.

1.1. Texture semantic analysis

In the field of texture semantics analysis, most researchers focus on semantic categories of texture images. Shin, Kim and Kim adopted eight categories (romantic, natural, casual, elegant, chic, classic, dandy and modern) to predict certain human emotional concepts of textile images [3]. Kim, Kim, Jeong, et al. use six pairs of adverse semantic features (weak/strong, sober/gay, dark/light, dismal/cheerful, warm/cool, soft/hard) to classify textile images

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[4,5]. Kim, Shin and Kim applied ten pairs of adverse semantic features (romantic/unromantic, clear/unclear, natural/unnatural, casual/un-casual, elegant/inelegant, chic/un-chic, dynamic/static, classic/non-classic, dandy/non-dandy, modern/non-modern) to identify emotions of textile images using neural networks [6]. Li et al. put forward a neural network approach to extract the image description framework, and then modeled the vagueness of human visual perception and extracted the fuzzy semantic feature [7]. Lee et al. investigated the impact of physical appearance attributes (in terms of color and shape) on affective feelings of 2D and 3D objects [8]. Lucassen et al. conducted an experiment to measure and model how color emotions change when textures are added to color samples [9]. Solli and Lenz investigated the emotional response to multicolored images through psychophysical experiments in which both category scaling and interval scaling method were used [10]. Wang et al. studied the relationship between texture semantics and textile images, and proposed linear regression, k-nearest neighbor (KNN) and Multi-layered perceptron (MLP), three parametric mapping models to predict texture semantics from textile images [11]. Reinecke et al. demonstrated a means to predict the initial impression of aesthetic properties based on perceptual models of a website's colorfulness and visual complexity [12].

1.2. *Neural correlates of esthetics*

The search for the source of beauty, of whether it resides in the object apprehended or in the perceiving subject, has excised the speculation of scientists and philosophers throughout the ages. It seems unlikely that studies of the brain will ever be able to wholly explain how we respond to art. Therefore, a new field of research emerges at the intersection of psychological esthetics, neuroscience and human evolution, which is called neuroaesthetics. As neuroaesthetics comes of age, it has taken advantage of the lessons learned from more mature domains of inquiry [13–15]. Recent advances in neuroaesthetics fields include theoretical works as well as with a number of experiments approaching the study of preference, appraisal, and aesthetic judgment with neuroscientific methods such as functional magnetic resonance image (fMRI), positron emission tomography (PET), magneto encephalography (MEG), or electroencephalography (EEG). Kawabata and Zeki used functional magnetic resonance image (fMRI) to address the question of whether there are brains areas that specifically engaged when subjects view paintings that they consider to be beautiful [16]. Their experimental results show that the perception of different categories of painting are associated with distinct and specialized visual areas of the brain, that the orbito-frontal cortex is differentially engaged during the perception of beautiful and ugly stimuli. Vartainan and Goel used fMRI to determine the neuroanatomical correlates of aesthetic preference for paintings and pointed out that activation in right caudate nucleus decreases in response to decreasing preference and that activation in bilateral occipital gyri, left cingulate sulcus, and bilateral fusiform gyri increase in response to increasing preference[17]. Jacobsen et al. used fMRI to investigate the neural correlates of aesthetic judgments of beauty of geometrical shapes and found out that beautiful judgments enhanced blood oxygen-level dependent (BOLD) signals not only in the frontomdedian cortex, but also in the left intraparietal sulcus of the symmetry network [18]. Kirk et al. observed bilateral activation in the entorhinal cortex in the main effect [G–C] irrespective of the actual aesthetic ratings and midbrain dopaminergic systems was involved in reward expectation to modulate aesthetic memory formation in the hippocampus [19]. Calvo-Merino et al. applied repetitive transcranial magnetic stimulation (rTMS) over candidate brain areas to disrupt aesthetic processing while healthy volunteers mad aesthetic preference judgments between pairs of dance postures, or control non-body stimuli [20]. By means of MEG, Cela-Conde et al. identified activity in the left dorsolateral prefrontal cortex and this activity was especially significant when participants judged stimuli as beautiful, as compared to being non-beautiflu, between 400 and 1000 ms after stimuli onset [21]. An important achievement of Jacobs's research is that a brain region that assesses beauty should show beauty-level-dependent activation during the beauty judgment task, but not during other, unrelated tasks [22]. Cattaneo, Lega and Flexas suggested the left dorsolateral prefrontal cortex plays a critical role in aesthetic judgments and aesthetic appreciation of representational paintings and photographs can be increased by applying anodal transcranial direct current stimulation [23]. Using EEG, Noguchi and Murota investigated neural activity when subjects with no professional experience in art viewed images of sculpture and performed a five-scale rating of how appealing they were, and observed a rapid integration of visual and contextual perception of information in the brain[24]. Zeki et al. used fMRI to image the activity in the brains of 15 mathematicians when they viewed mathematical formulae, and found that the experience of mathematical beauty correlates with the same brain region, as the experience of beauty derived from other sources [25]. Chatterjee and Vartanian suggested aesthetic experiences which emerge from the interaction between sensory-motor, emotion-valuation, and meaning–knowledge neural systems [26]. The sensory-motor systems can automatically process and recognize the elemental features of aesthetic objects [27]. The emotion-valuation system of the brain contributes to aesthetic experience includes the orbitofrontal and medial frontal cortex, ventral striatum, anterior cingulate and insula [28]. The contribution of the meaning-knowledge system is least known, partly because its manifestations are widely distributed throughout the brain and it varies substantially across individuals, cultures, and historic epochs [29]. In summary, it is well established that aesthetic appreciation is related with activity in several different brain regions through instrumental strategy, but which is just the beginning of neuroaesthetics [30]. The relation between cognitive and neural processes involved in aesthetic appreciation is highly complex and intricate. The identification of the neural correlates of beauty has been primarily exploited in the most prior researches.

1.3. *Modeling esthetics perception of visual arts*

How can we appreciate beauty and whether there are brain areas that are specifically engaged when we view paintings that are considered to be beautiful have been scientifically explored by neuroscientists and neuropsychologist to find out the cognitive and neural underpinnings of aesthetic appreciation. The main objective of neuroaesthetics is to characterize the neurobiological foundations and evolutionary history of the cognitive and affective processes involved in aesthetic experiences and artistic and other creative activities [31]. Interest in the field of neuroaesthetics has grown remarkably during the last years. Neuroaesthetics is a relatively young field within cognitive neuroscience, concerned with the neural underpinnings of aesthetic experience of beauty, particularly in visual art [32]. Datta et al. employed support vector machines and classification trees to recognize the esthetically pleasing images from the displeasing ones, and used linear regression on polynomial terms of features to infer numerical esthetics ratings [33]. By recording the brain activity of 10 male and 10 female participants while they were appreciating examples of artistic and natural visual stimuli, Cela-Conde et al. explored possible differences between men and women's neural correlates of aesthetic preference [34]. Using fMRI, Huang et al. identified that authenticity of arts had no direct effect on the cortical visual

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