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An analysis of fear of crime using multimodal measurement

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ABSTRACT

Fear of crime, which may be present without experiencing an actual crime, can restrict one's daily physical and mental activities and reduce quality of life. In previous research, fear of crime was measured by regional surveys. Though useful for confirming group characteristics, regional surveys cannot measure in real-time, assess individual characteristics, or provide an objective measure of anxiety. Since the causes and effects of fear of crime are highly individualized, we have developed a protocol to measure physiological signals in concert with existing surveys; this system can verify an individual's fear of crime characteristics in real time. Subjects were shown 6 clips of actual pedestrian environments (day/night of a commercial street scene, day/night of a residential street scene, day/night of a natural street scene). To ease immersion of the subjects into the scenes, clips were produced from the subjects' first-person point of view. Subjects were divided into two groups (Group1: N = 14, age, 22 ± 1.66 years; Group2: N = 13, age 21 ± 1.35 years) based on their fear intensity as reported on our pre-recording survey; electroencephalographic (EEG), electrocardiographic (ECG), and galvanic skin response (GSR) signals were compared between groups. They were then assessed via video for comparative purposes. Our results demonstrated that the physiological signals were dependent on how conscious an individual was of his or her own fear of crime. We found significant differences between the two groups for all video clips except for daytime commercial street and nighttime natural street; these data suggest that individual characteristics are important in measuring fear of crime.

1. Introduction

With improving quality of life, social demand for security against crime also rises. Despite not personally experiencing crimes, disasters, and accidents, people experience such situations vicariously through the media and their social circles, leading to a rising fear of crime in individuals. To address this, existing research has been used to establish a crime prevention map, based on areas where crime has occurred in the past and other environmental factors [1,2]. However, because this map only deals with data on past crimes, it cannot be used to examine the fear of crime that related to individual characteristics of people in areas with little or no previously recorded crimes.

Objectively, the fear of crime and actual crime rate have no direct correlation [3,7,8]. Yet many studies have indicated that the fear of crime affects an individual's mental health and physical activity. Lorenc et al. [3,4] examined the effects that the fear of crime had on physical and social environments, and determined that there should be more focus on how the fear of crime can potentially mediate the effects of community-level environmental factors related to health and well-being. In addition, Lorenc's group developed a putative framework for the relationship between fear of crime, environment, and individuals' mental health and well-being. In this framework, he has argued that both crime and fear of crime have significant effects on well-being. In fact, they found significant effects of fear of crime on the walking behavior of residents. By establishing a crime map that better reflects this information, improvements in both individual and community well-being can be attained [3–6].

Research that measures fear of crime is mostly carried out by surveying a large population of a selected region. This can identify general results for the region, but can only rarely identify individual factors. Moreover, differences in populations and between regions can produce significantly different results. For example, when analyzing the effect of fear of crime on performing a physical activity, Roman et al. [7] found that performance of an African-American population living in urban public housing was unaffected by fear of crime. However, many studies on other populations have demonstrated significant effects of fear of crime on the population's activity [3–6]. Such wide differences imply that fear of crime

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needs to be analyzed on smaller groups or in individuals as well. In addition, Lim et al. [8] found that responses differed based on how the particular survey for a given population was written, which limits the validity of comparisons. In addition, when measuring fear of crime, many studies have argued that emotional aspects and perceived risk of crime should be distinguished [9–11], but Lim and colleagues noted that the two factors could not be clearly differentiated through a survey.

To overcome the survey-related limitations, this study used physiological signals as a more objective measure of emotional state (i.e., fear/anxiety), and to enable identification of individual characteristics. Physiological signals used for measuring emotion include pupillary reflex, electrocardiogram (ECG), electromyogram (EMG), electroencephalogram (EEG), galvanic skin response (GSR), temperature, and heart rate (HR) [12–16,19,40–41]. These measures can continuously analyze real-time emotional state, unlike the surveys, which involve remembering past memories.

EEG in humans uses scalp electrodes to quantify regional electrical activity in the cerebral cortex; the most commonly studied EEG frequency bands are delta (δ: 1–4 Hz), theta (θ: 4–8 Hz), alpha (α: 8–13 Hz), beta (β: 13–30 Hz), and gamma (ϒ: 30–50 Hz). Current studies propose that frontal EEG power asymmetry represents emotional processing [17,18,33,36,37]. The study of EEG power has been important in brain asymmetry (inter-hemispheric activity differences) and emotion. Broadly speaking, the left regions are specialized for the expression of positive emotion, whereas the right regions are involved in the expression of negative emotions. Davidson et al.'s research has shown that left frontal EEG activity was high for positive emotions, while right frontal EEG activity was high for negative emotions [21,22]. Baumgartner et al. has argued that compared to negative emotions, a positive emotion resulted in the increase of EEG activity in the left hemisphere [20]. The parietal cortex is believed to modulate affective processing and emotion-related arousal [34–36]. Sarlo et al. suggested that disgust related to alpha power changes in the parietal lobe [37], while Shutter et al. noted a highly significant relationship between right parietal beta EEG activity and attentional responses to an angry face [34]. Balconi et al. has argued that right parietal gamma spectral changes are involved in evaluating emotions as an index of consciousness [38]. Li et al. has shown gamma-band activity to be appropriate for emotion classification [23]. In addition, Nie et al. suggested that left frontal and right temporal lobe gamma activity served as a marker for emotion recognition [24].

ECG measures the electrical activity of the heart in terms of the variation of the cardiac electrical potential over time. The most commonly used cardiac measure is heart rate variability (HRV) [12,25]. It can be used as a factor for examining emotional states [26] and is measured by RR interval variation. R is a peak of the QRS complex, a major signal in the ECG wave. Folino et al. measured the QRS complex during mental stress and found a positive correlation between the energy of the QRS complex and task difficulty [27]. Liu et al. suggested that HRV is a valuable physiological indicator, which could measure the expression of fear memories in mice [39].

GSR measures skin resistance towards electrical conduction between two electrodes, which increases with increasing stimulation (and anxiety/stress) due to increased sweating. GSR in the palm and sole is sensitive to mental stimulation and environmental conditions [28]. This is a particularly useful method for measuring degree of arousal. Liu et al. has proposed GSR as a method for evaluating the emotional intensity of happiness and grief, testing its feasibility in real-life affective computing applications [38]. Vijaya et al. used GSR to categorize emotions in a study utilizing video clips of the emotions of fear, disgust, happiness, and surprise. The 10 subjects showed the highest percentage classification of arousal with fear (80.65%), among the 4 emotions tested [29].

Most of the above studies used protocols where the distinction between negative and positive emotions was clear. Fear of crime is a negative emotion, and represents the strongest arousal level among the negative emotions [29]. In this study, we began with a survey to identify subjects as low-intensity or high-intensity fear of crime. We divided them into two groups based on the fear intensity and combined electrophysiological recordings with their perceived fear of crime. We approached fear of crime from an individual perspective to identify those characteristics that would not be found in regional surveys. Our aim was to provide a "safe route" that would ultimately reduce fear of crime in each pedestrian, thereby reducing stress, improving their mental health, and enhancing their quality of life.

2. Materials and methods

2.1. Subjects

We enrolled 27 participants (10 men, mean age 22.3 ± 1.70 years; 17 women, mean age 21.05 ± 1.34 years). We deliberately restricted the age to approximately $20 \sim 25$ years, because the focus herein was on the effects of environmental factors on fear of crime, and limiting the age range allowed us to exclude other factors that may have affected the physiological signals. Because this study analyzed physiological signals, some of our previously-used methods from earlier quantitative (survey-based) research were incompatible with this study's protocols. First, since the time required for the experiment exceeds 2 h, the number of experiments that can be performed per day was limited. Second, the cost of equipment used to measure the physiological signals is significant, especially when compared to studies based on surveys alone. Finally, because of the nature of the signals being analyzed, interference by extraneous signals not related the experimental stimulus needed to be limited, so it was necessary to select the most physically healthy subjects of age 20–25 years. To meet these conditions, many studies will typically include 10–30 subjects; therefore, we concluded that the statistical analysis of 27 subjects in this experiment would provide enough power.

When recruiting participants, we accepted all participants meeting the age limit and health requirements, and divided them into two groups (LFG and HFG) according to their responses on the survey of fear of crime. However, any subject for whom the experiment was interrupted due to sleepiness, or for whom the data were corrupted by excessive movement artifacts, was removed from the group prior to data analysis. The study was done with the approval of the IRB of the Catholic University of Korea. All subjects were briefed on the study and provided informed written consent (in accord with the Helsinki Declaration). Fig. 1 depicts the overall study protocols. After completion, participants were paid a small remuneration.

2.2. Survey and behavioral testing

All enrolled participants first filled out a survey on fear of crime. After completing the survey, a subject was given a description of the physiological signal measurement apparatus. The subject was then prepared for ECG and GSR measurements by applying the appropriate electrodes. Lastly, EEG electrodes were attached, and the video clips used to assess fear of crime were played. Because accurate measurement of the physiological signals was our top priority, participants could not actually walk without creating movement artifacts, so we used real-time video clips of walking down a street. In order to best approximate the actual conditions, we instructed each subject to think of the clip as a first-person point of view (his/her own point of view), and created an environment in which