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The Effect of Emotion on Keystroke: An Experimental Study Using Facial Feedback Hypothesis

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Abstract—**The automatic emotion recognition technology is an important part of building intelligent systems to prevent the computers acting inappropriately. A novel approach for recognizing emotional state by their keystroke typing patterns on a standard keyboard was developed in recent years. However, there was very limited investigation about the phenomenon itself in the previous literatures. Hence, in our study, we conduct a controlled experiment to collect subjects' keystroke data in the different emotional states induced by facial feedback. We examine the difference of the keystroke data between positive and negative emotional states. The results prove the significance in the differences in the typing patterns under positive and negative emotions for all subjects. Our study provides an evidence for the reasonability about developing the technique of emotion recognition by keystroke.**

I. Introduction

Emotion plays a vital role in our daily life, we experience emotion by feeling happy, angry, sad, and various emotions. Because it is human nature to pursue happiness and avoid pain, these feelings will affect our mental and physical health [1, 2].

Nowadays, graphics and computing capabilities are much more powerful and stronger. Despite the fact of this, the computer interactive applications still have considerable usability problem, that is, applications do not understand or adapt to users' context such as emotional states. As a result, the applications always provide inappropriate feedbacks, interrupt the user at the wrong time, and increase frustration.

Affective Computing, which was firstly proposed by Picard [3], was aimed to assist human by developing intelligent emotion recognition technologies that could detect the changes of emotions hold by human. Many approaches for detecting users' emotions have been demonstrated to be useful in emotion recognition, for example, by facial expression, in which aims on modeling the visually distinguishable facial movements [4]; by speech, in which researchers have utilized the acoustic features include pitch, intensity, duration, and spectral data [5]; and by human psycho-physiological data [6]. However, there are two main problems preventing wide scale use: they may be intrusive to the user, and may require specialized equipment.

Therefore, a new technique for recognizing users' emotional state by a standard keyboard input device was investigated in recent decades. The major advantages are: (1) it is a low-cost way that doesn't require specialized equipment and, (2) will not alter users' emotional states with a non-intrusive standard input. Zimmerman et al. [7] describe a method to correlate user interactions (keyboard and mouse) with emotions. The authors found significant differences between the neutral state and other emotional states, but were unable to distinguish between the induced states. Vizer et al. [8] used keystroke timing features in conjunction with linguistic features to identify cognitive and physical stress. They achieved correct classifications of 62.5% for physical stress and 75% for cognitive stress. Clayton et al. [9] used the keystroke features extracted from the real-world collected data to identify emotional states. The results show promise with high accuracies in identifying 6 emotions. In line with former research, we've also proposed an emotion recognition technique based on mouse record, keystroke and a self-report database collected from subjects in real-world situations. Our approach was demonstrated for being fairly effective [10]. Our proposed method was also used in a user-independent intelligent system that can report the emotional state of students to the tutor in an e-learning environment [11].

Since several studies have demonstrated the usability of such phenomenon in the applications, phenomenon itself is still remaining unclear in our point of view. The effect of emotion on keystroke as a research field has not been empirically studied under in a controlled experiment. Hence, the goal of this study is to validate the hypothesis about the existence of the difference on typing pattern between different emotional states. The experimental results are of great interest both for application and scientific research.

II. Method

A. Eliciting emotion

Before starting the experiment, we must realize how to induce the emotion of the subjects. From the common sense of view, for instance, people encounter an eliciting event such as seeing a cute baby, feel happy and then smile. However, William James proposed the different direction of the emotion elicitation [12]. His theory is that people feel unhappy because

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they cry, happy because they smile, angry because they strike, and not that they cry, smile, or strike, because they are sorry, happy, or angry. Consequently, there are two ways to induce people's emotion: (1) using the picture, film, or music or (2) emotional behavior as a stimuli. The drawback of the former is that not everyone has the same feeling about the same picture (film or music), while the latter guarantees the same extent on feeling. For example, when you are forced to smile, you became happy.

Facial feedback hypothesis, which was proposed by Laird [13] based on William's thesis, states that facial movement can influence emotional experience. Strack, Martin, and Stepper tested the hypothesis [14]. They instructed subjects to hold a pen in their teeth, lips, or non-dominant hand. The first produces a smile-like pattern, the second inhibits it, and the third is a control condition. Individuals found cartoons more humorous during the simulated smile and less humorous when their smiles were suppressed.

Our study adopt facial feedback as our method to induce subjects' emotion in our experiment in order to validate our hypothesis about the difference between typing patterns under different emotional states.

B. Experiment design

Fifteen university student participated our study (mean age = 23.4 years old, standard deviation = 1.45; 10 men, 5 women). All subjects self-reported that they were healthy, with no history of brain injury, cardiovascular problem, and had normal or corrected-to-normal vision and normal range of finger movement. We asked our subjects to type a fixed number sequence "67829751" under different emotional states induced by the facial feedback. We follow the two conditions used in the experiment conducted by Strack et al. in 1988 [14], that is, "teeth" and "lip". The former induce positive emotion, and the latter contrary. During the whole experiment period, the keystroke data were recorded. The subjects typed on the number-pad located at the right side of the standard keyboard. The experiment was a Single-Blind Test, that is, the experimenter didn't tell the subjects about why they were holding a pen using their mouth (the induction method using facial expression). Number sequence was used in our study instead of the alphabet sequence to avoid possible interference caused by linguistic context. Using a fixed number sequence throughout the experiment guaranteed the consistency of each experimental trial.

The experimental procedure is composed of four parts which are shown in Fig. 1.When the subject arrived at the laboratory, he or she will firstly be asked to complete 10 math quizzes in order to make his (her) emotional state back to the baseline (i.e. the neutral state). The math quizzes used for all subjects were randomly chosen on an internet open source from National Central University [15]. After that, in part Ⅱ is the training section in which the subjects continuously type the fixed number sequence. The purpose of this part was to ensure that the difference on typing pattern was caused by the designed different emotional states, but not due to the improvement caused by being more familiarity to the typing material during the experiment. After that are the main parts of the experiment (part Ⅲ and part Ⅳ). Subject was instructed to hold a pen in teeth or lip for 1 minute, and then starting typing the number sequence showing on the monitor for 1 minute with the pen on the mouth. And then was a 30-second break between different emotional states. The experiment was held in the next day in which the order of part Ⅲ and part Ⅳ exchanged to eliminate the fatigue and sequential effect.

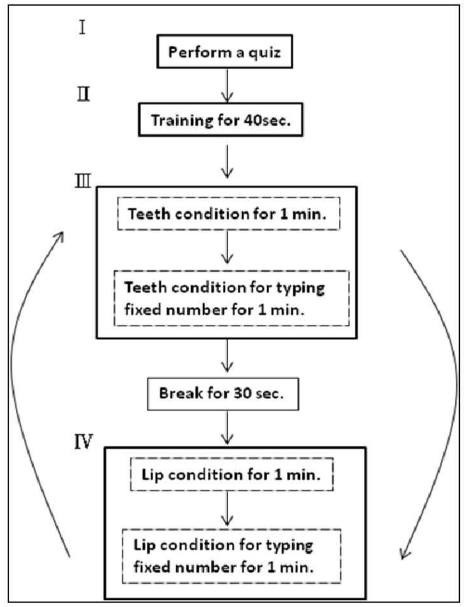

Figure 1. Flow chart of the experimental procedure.

C. Data analysis

The keystroke data consists of key press events, release events, unique codes of each key, and a timestamp of the time (tick of the C# programming language) the key event occurred, collected by the software written by C#, installing in the laboratory computer. We extracted features: duration and latency, from these data. The duration is the time elapsed between key press to key release, and the latency is the time elapsed from one key release event to the next key press [16]. These two categories of the features have been extensively used in previous studies from single keystroke to multi-keystroke [17]. The features we extracted in this study contain single keystroke and multi-keystroke.

The raw data firstly proceeded a pre-processing to eliminate all typing mistakes (e.g., if the subject typed "678297541", in which a "4" is misplaced in the number sequence, the whole number sequence would be regarded as a mistake). After pre-processing, we selected 20 sequence trials from part Ⅲ in the first experimental day, and concatenated with 20 sequence trials from part Ⅳ in the second experimental day. Therefore, we got 40 trials of number sequence of the positive emotional state for each subject. Similarly, concatenating part Ⅳ in the first experimental day and part Ⅲ in the second experimental day would get 40 trials of number sequence of the negative emotional state for each subject. All keystroke features were extracted and submitted to independent samples t-tests to validate our hypothesis. We also examine the effects of gender.

TABLE I. THE RESULTS OF SINGLE KEYSTROKE FEATURES FOR ALL SUBJECTS

Subject No.	Emotion states	Keystroke(duration)								Keystroke(latency)						
		6	7	8	2	9	7	5	1	6	7	8	2	9	7	5
Subject1(F)	Positive	0.12±0.03	0.09±0.03	0.07±0.02	0.09±0.02	0.11±0.02	0.09±0.03*	0.1±0.02	0.1±0.02	0.05±0.04	0.08±0.06	0.16±0.03	0.13±0.03	0.04±0.03*	0.12±0.02*	0.07±0.03
	Negative	0.12±0.03	0.09±0.03	0.07±0.02	0.1±0.02	0.11±0.03	0.07±0.03*	0.1±0.03	0.1±0.03	0.07±0.05	0.08±0.06	0.16±0.05	0.13±0.03	0.07±0.05*	0.14±0.05*	0.08±0.06
Subject2(F)	Positive	0.12±0.03	0.08±0.04*	0.07±0.03	0.09±0.02	0.11±0.02*	0.05±0.02	0.11±0.02	0.08±0.02*	0.07±0.04*	0.05±0.03	0.16±0.06	0.23±0.1	0.05±0.02	0.07±0.04	0.06±0.06
	Negative	0.11±0.02	0.1±0.02*	0.07±0.03	0.09±0.01	0.12±0.03*	0.05±0.02	0.12±0.02	0.06±0.04*	0.11±0.06*	0.05±0.03	0.17±0.06	0.2±0.03	0.06±0.02	0.06±0.03	0.06±0.05
Subject3(F)	Positive	0.09±0.01*	0.08±0.02	0.08±0.02*	0.09±0.02*	0.08±0.01	0.08±0.01	0.09±0.02	0.08±0.02*	0.19±0.08	0.27±0.2	0.18±0.1	0.24±0.2	0.16±0.05	0.17±0.09	0.11±0.03
	Negative	0.08±0.01*	0.08±0.01	0.09±0.02*	0.08±0.01*	0.08±0.01	0.08±0.01	0.08±0.01	0.07±0.02*	0.18±0.15	0.2±0.16	0.21±0.18	0.24±0.19	0.16±0.08	0.16±0.09	0.12±0.04
Subject4(M)	Positive	0.08±0.02	0.08±0.02	0.08±0.02	0.09±0.03	0.08±0.02	0.08±0.02	0.09±0.02	0.09±0.02	0.14±0.09	0.11±0.02	0.21±0.12	0.14±0.05*	0.16±0.09*	0.1±0.03*	0.11±0.04
	Negative	0.09±0.02	0.07±0.02	0.07±0.02	0.09±0.02	0.08±0.02	0.09±0.02	0.08±0.02	0.08±0.02	0.11±0.06	0.1±0.02	0.2±0.09	0.11±0.02*	0.11±0.04*	0.08±0.02*	0.11±0.03
Subject5(F)	Positive	0.09±0.02	0.12±0.03	0.09±0.02	0.08±0.02	0.12±0.02*	0.1±0.02	0.13±0.03	0.1±0.03	0.15±0.05	0.09±0.03	0.17±0.03	0.17±0.02	0.1±0.03	0.14±0.01	0.08±0.03
	Negative	0.1±0.02	0.12±0.02	0.1±0.03	0.08±0.02	0.12±0.02*	0.11±0.02	0.13±0.03	0.11±0.03	0.14±0.02	0.09±0.05	0.17±0.03	0.16±0.02	0.1±0.03	0.15±0.03	0.09±0.04
Subject6(M)	Positive	0.13±0.05	0.07±0.04	0.08±0.01*	0.07±0.01	0.1±0.02*	0.08±0.02	0.1±0.03	0.07±0.03*	0.09±0.07	0.14±0.1	0.17±0.02	0.17±0.03	0.08±0.06	0.14±0.04	0.09±0.07
	Negative	0.14±0.05	0.08±0.04	0.07±0.03*	0.07±0.02	0.11±0.03*	0.08±0.02	0.09±0.03	0.05±0.02*	0.09±0.06	0.11±0.05	0.15±0.05	0.17±0.03	0.07±0.06	0.15±0.04	0.08±0.05
Subject7(M)	Positive	0.1±0.02*	0.07±0.02	0.06±0.02	0.09±0.01	0.1±0.02*	0.07±0.02*	0.08±0.01	0.09±0.01	0.09±0.02*	0.08±0.02*	0.14±0.01*	0.23±0.04*	0.07±0.02*	0.13±0.02*	0.1±0.02*
	Negative	0.11±0.02*	0.07±0.01	0.06±0.01	0.09±0.01	0.11±0.01*	0.08±0.01*	0.07±0.01	0.08±0.02	0.1±0.03*	0.11±0.03*	0.16±0.03*	0.29±0.06*	0.08±0.02*	0.15±0.03*	0.13±0.02*
Subject8(M)	Positive	0.09±0.03	0.09±0.02	0.08±0.01	0.09±0.01	0.09±0.02*	0.08±0.01	0.08±0.01	0.09±0.01	0.13±0.03	0.13±0.06	0.16±0.04	0.18±0.11	0.12±0.05	0.14±0.02	0.11±0.03
	Negative	0.08±0.02	0.09±0.02	0.08±0.02	0.09±0.01	0.09±0.02*	0.09±0.01	0.08±0.02	0.09±0.02	0.12±0.03	0.12±0.06	0.15±0.02	0.16±0.05	0.11±0.02	0.14±0.03	0.11±0.02
Subject9(M)	Positive	0.16±0.03*	0.07±0.04*	0.09±0.02	0.11±0.03*	0.1±0.06	0.07±0.04*	0.09±0.03	0.09±0.03	0.07±0.06	0.1±0.03	0.18±0.04	0.04±0.04*	0.08±0.06	0.11±0.04	0.14±0.02*
	Negative	0.14±0.02*	0.08±0.03*	0.09±0.02	0.13±0.03*	0.1±0.06	0.09±0.04*	0.09±0.02	0.10.02	0.05±0.02	0.11±0.03	0.17±0.08	0.02±0.02*	0.09±0.05	0.11±0.03	0.13±0.02*
Subject10(M)	Positive	0.11±0.02*	0.12±0.04*	0.1±0.03	0.13±0.03	0.13±0.03*	0.09±0.02*	0.11±0.01	0.11±0.03	0.23±0.12	0.17±0.13	0.34±0.15*	0.33±0.15	0.19±0.06	0.25±0.06*	0.22±0.11
	Negative	0.12±0.02*	0.1±0.03*	0.09±0.04	0.13±0.02	0.14±0.02*	0.1±0.02*	0.11±0.02	0.12±0.02	0.25±0.26	0.11±0.12	0.24±0.23*	0.35±0.27	0.28±0.28	0.21±0.06*	0.21±0.08
Subject11(F)	Positive	0.07±0.02*	0.07±0.02	0.07±0.02*	0.07±0.02*	0.07±0.02*	0.07±0.02*	0.07±0.02*	0.07±0.02*	0.31±0.22	0.15±0.13	0.28±0.16	0.15±0.11	0.22±0.15*	0.14±0.05*	0.16±0.17
	Negative	0.09±0.03*	0.08±0.02	0.09±0.02*	0.09±0.03*	0.09±0.02*	0.08±0.02*	0.09±0.03*	0.09±0.02*	0.24±0.13	0.11±0.08	0.24±0.11	0.11±0.05	0.14±0.06*	0.11±0.04*	0.12±0.03
Subject12(M)	Positive	0.11±0.02	0.11±0.02	0.11±0.02*	0.1±0.02	0.11±0.02	0.08±0.01*	0.09±0.02	0.1±0.02	0.15±0.04	0.12±0.03	0.28±0.09*	0.17±0.09	0.13±0.03	0.16±0.03	0.16±0.04
	Negative	0.11±0.02	0.11±0.02	0.12±0.02*	0.11±0.02	0.11±0.02	0.09±0.02*	0.09±0.02	0.11±0.02	0.12±0.02	0.11±0.02	0.24±0.04*	0.14±0.03	0.13±0.02	0.16±0.02	0.15±0.02
Subject13(M)	Positive	0.09±0.03	0.08±0.03	0.08±0.02	0.1±0.03	0.09±0.03	0.08±0.03	0.08±0.03	0.09±0.03	0.1±0.03	0.16±0.17	0.16±0.06	0.11±0.07	0.1±0.08	0.16±0.05	0.11±0.03*
	Negative	0.1±0.02	0.08±0.02	0.08±0.02	0.1±0.03	0.09±0.03	0.07±0.02	0.07±0.02	0.1±0.03	0.09±0.02	0.13±0.06	0.17±0.15	0.09±0.06	0.1±0.08	0.15±0.03	0.1±0.02*
Subject14(M)	Positive	0.12±0.02	0.09±0.03*	0.07±0.03	0.09±0.02*	0.12±0.03*	0.09±0.04*	0.12±0.05*	0.1±0.03	0.17±0.08	0.09±0.05*	0.13±0.09	0.13±0.05	0.11±0.1	0.11±0.04*	0.12±0.05*
	Negative	0.12±0.02	0.13±0.03*	0.07±0.03	0.1±0.03*	0.1±0.03*	0.11±0.03*	0.14±0.03*	0.09±0.04	0.14±0.04	0.06±0.04*	0.13±0.12	0.13±0.09	0.08±0.03	0.09±0.04*	0.09±0.05*
Subject15(M)	Positive	0.09±0.03*	0.1±0.04*	0.09±0.03*	0.11±0.03	0.09±0.05*	0.1±0.03*	0.08±0.03*	0.09±0.03*	0.16±0.04	0.14±0.06*	0.2±0.09*	0.09±0.07	0.17±0.11*	0.15±0.03	0.15±0.05*
	Negative	0.07±0.02*	0.08±0.02*	0.07±0.02*	0.1±0.03	0.07±0.04*	0.08±0.02*	0.07±0.02*	0.07±0.02*	0.15±0.06	0.12±0.03*	0.15±0.04*	0.09±0.09	0.12±0.04*	0.14±0.05	0.13±0.03*
All males	Positive	0.10±0.03	0.08±0.03	0.08±0.02	0.09±0.02	0.1±0.03	0.08±0.02*	0.09±0.02	0.08±0.02	0.13±0.07	0.12±0.08*	0.19±0.10*	0.15±0.10	0.12±0.08	0.14±0.05*	0.13±0.06*
	Negative	0.10±0.03	0.08±0.02	0.08±0.02	0.10±0.02	0.10±0.03	0.08±0.02*	0.09±0.02	0.08±0.03	0.12±0.09	0.10±0.05*	0.17±0.10*	0.15±0.12	0.11±0.10	0.13±0.04*	0.12±0.04*
All females	Positive	0.09±0.02	0.08±0.03*	0.07±0.02*	0.08±0.01	0.09±0.02*	0.07±0.02	0.09±0.03*	0.08±0.02	0.15±0.14	0.12±0.13	0.19±0.09	0.18±0.11	0.11±0.10	0.12±0.06	0.09±0.09
	Negative	0.10±0.02	0.09±0.03*	0.08±0.02*	0.08±0.02	0.10±0.03*	0.07±0.02	0.10±0.02*	0.08±0.03	0.14±0.11	0.10±0.09	0.18±0.10	0.16±0.09	0.10±0.06	0.12±0.06	0.09±0.04
All subjects	Positive	0.10±0.03	0.08±0.03*	0.08±0.02	0.09±0.02*	0.09±0.03	0.08±0.02	0.09±0.02	0.08±0.02	0.13±0.10	0.12±0.10*	0.19±0.10*	0.16±0.11	0.11±0.08	0.13±0.05*	0.11±0.07
	Negative	0.10±0.03	0.09±0.03*	0.08±0.02	0.09±0.02*	0.10±0.03	0.08±0.02	0.09±0.03	0.08±0.03	0.13±0.10	0.10±0.07*	0.17±0.10*	0.15±0.11	0.11±0.09	0.13±0.05*	0.11±0.05

* symbol and gray shading represents p-value<0.05

M: male, F: female

Unit: second

TABLE Ⅱ. THE RESULTS OF ALL KEYSTROKE FEATURES AND THE AMOUNT OF SUBJECTS CORRESPONDED

Features	p<0.2	p<0.05	p<0.01	Features	p<0.2	p<0.05	p<0.01	Features	p<0.2	p<0.05	p<0.01	Features	p<0.2	p<0.05	p<0.01
6D	8	6	4	82D	6	3	2	7b1D	6	6	4	71L	9	8	3
67D	8	5	4	89D	6	3	2	5D	5	3	1	82L	6	4	2
68D	8	4	3	87bD	8	4	2	51D	8	4	4	89L	6	3	1
62D	7	5	3	85D	8	6	2	1D	8	6	3	87bL	9	7	2
69D	10	4	2	81D	8	6	5	67L	7	3	2	85L	9	7	2
67bD	8	6	2	2D	6	4	4	68L	7	5	3	81L	8	8	4
65D	9	6	4	29D	7	4	2	62L	7	4	4	29L	7	3	3
61D	9	7	4	27bD	7	4	4	69L	9	3	3	27bL	7	4	2
7D	6	5	2	25D	8	5	4	67bL	7	7	3	25L	9	5	2
78D	9	5	2	21D	8	5	5	65L	8	7	3	21L	11	8	3
72D	8	4	3	9D	9	9	3	61L	9	7	3	97bL	8	5	4
79D	6	5	3	97bD	9	7	5	78L	7	3	2	95L	8	7	6
77bD	9	5	3	95D	9	6	5	72L	6	2	2	91L	9	8	6
75D	9	6	2	91D	8	6	6	79L	6	3	2	7b5L	6	6	4
71D	9	6	5	7bD	10	8	5	77bL	7	6	2	7b1L	11	7	6
8D	6	5	3	7b5D	7	5	3	75L	8	7	2	51L	9	5	1

III. RESULTS AND DISCUSSION

The results are shown in Table Ⅰ and Table Ⅱ. Since there might be individual difference between subjects, we show the average elapsed time and standard deviation for all subjects in every single keystroke feature. Table Ⅰ shows all results of duration and latency and highlights the difference between two emotional states. Most subjects show significant differences in duration at least one keystroke except subject 4 and 13. Subject 11 and 15 show significant differences in the all of seven keystrokes. Although there are less features of latencies show statistically significant result, there are only 3 subjects showing no difference in overall features related to latencies. For example, we found that subject 7 shows very different typing patterns in the latency between two emotional states. There are no significant differences in the latency features of female subjects. For all subjects, as shown in the last two row of Table Ⅰ, the key "7" shows significant differences in both duration and latency. The reason for those subjects who have fewer features showing significant results such as subject 5 and subject 13, possibly is that their emotion were not induced successfully or not strong enough. Another possibility is the subjects' habit of holding something on their mouth.

Table Ⅱ provides detailed analysis on the relationship of all keystroke features in regard to the number of subjects that reached the levels of significance. The analysis includes single and multi-keystroke. For example, "68D" represents the "duration" of time elapsed between "6 press" and "8 release", and "68L" represents the "latency" of time elapsed between "6 release" and "8 press" and so on. "7b" represents the second "7", which is between "9" and "5" in the number sequence. The results reflected in this table indicate that all keystroke features could achieve the high level of difference.

The finding of Table Ⅱ shows that, as observed in Table Ⅰ, subjects seem to show more significant in duration than in latency. Duration might indicate the pressure which the subject giving on the keyboard, while latency could be regarded as the typing rate. The results imply that when subjects were in different emotional states, they might press the keyboard with different strength. The table also demonstrates the tendency of the data on supporting the hypothesis. The table also suggests that the features extracted from the middle of the number sequence show more promising results.

IV. CONCLUSION

By conducting the controlled experiment, we validate the hypothesis about the existence of the difference on typing pattern between two opposite emotional states. The experimental results support the theoretical foundation of the recent developed emotion recognition technology of which using keystroke information [7-11]. The keystroke data were also applied in authentication system in previous studies to make the system much secure from hacking [16, 17]. According to the results we presented, user's emotion might need to be noticed while adopting keystroke in authentication.

For suggested future work, it would be valuable to use different emotion eliciting method to induce more than two emotional states, or to have subjects type different keystroke sequence.

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