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How Fast are the Leaked Facial Expressions: The Duration of Micro-Expressions

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Abstract Micro-expression has gained a lot of attention because of its potential applications (e.g., transportation security) and theoretical implications (e.g., expression of emotions). However, the duration of micro-expression, which is considered as the most important characteristic, has not been firmly established. The present study provides evidence to define the duration of micro-expression by collecting and analyzing the fast facial expressions which are the leakage of genuine emotions. Participants were asked to neutralize their faces while watching emotional video episodes. Among the more than 1,000 elicited facial expressions, 109 leaked fast expressions (less than 500 ms) were selected and analyzed. The distribution curves of total duration and onset duration for the micro-expressions were presented. Based on the distribution and estimation, it seems suitable to define micro-expression by its total duration less than 500 ms or its onset duration less than 260 ms. These findings may facilitate further studies of micro-expressions in the future.

Keywords Micro-expression · Leaked facial expression · Duration · Action units

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Introduction

The term micro-expression now is widely recognized among mass media partly because of the wide-spread TV serials *Lie to Me*. Micro-expression is usually defined as a brief facial movement revealing an emotion that a person tries to conceal (Ekman 2006; Ekman and Friesen 1969). Although micro-expression has its theoretical implications as it demonstrates an interesting relationship between repressed emotions and facial expressions, the reputation of micro-expression is derived more from its potential practical applications in various areas. It is frequently mentioned in the field of lie detection because it was claimed to be an effective behavioral clue for lie and danger demeanor detections (Vrij 2008). Ekman (2009) even claimed that micro-expressions might be the most promising approach to detect deception. It was claimed that well-trained inspectors reached 80 % accuracy in lie detection based on micro-expression (Frank and Ekman 1997), which seems to be much more effective than other nonverbal cues. The Transportation Security Administration in the USA has already employed a technique called Screening Passengers by Observation Techniques (SPOT), which was largely based on the findings from micro-expression studies (Weinberger 2010). In the clinical field, micro-expressions may uncover emotions (regardless of patient's awareness to the emotion) which may help therapists to better understand patients' minds. Besides, micro-expression may be applied in the political field (Stewart et al. 2009) because it has significant emotional effects on the perceivers though it is considered almost imperceptible for untrained observers (Ekman and Friesen 1969). With these distinctive features and promising applications, studies about micro-expression are expected to flourish in coming years. However, the definition of micro-expression remains vague and indefinite.

The duration of expression is considered the main feature that distinguishes micro-expression from the conventional facial expressions (Shen et al. 2012). However, the duration of micro-expression remains inconsistent and at variance across different studies. Ekman *usually* considered 1/5 s as an upper limit for micro-expressions, suggesting that 1/5 s is the borderline between the conventional facial expressions and micro-expressions. However, no clear evidence has been given for such a division. Besides the classic "1/5 s", there are other versions of definition, including less than one-quarter of a second (Ekman 1985/2001), less than 1/3 s (Ekman and Rosenberg 2005), and less than half a second (Frank et al. 2009; Matsumoto and Hwang 2011). Thus, the duration of micro-expression, which is a key characteristic, is nevertheless confusing. In this respect, the term micro-expression has not been clearly defined. Without consensus on the duration of micro-expression, it is difficult to compare the results and communicate among the researchers, and thus hindering further research.

Therefore, it is necessary to collect sufficient micro-expressions and provide convincing evidence to define the duration. The fundamental characteristics of a micro-expression, according to Ekman's original definition, are involuntary leakage and fast speed (Ekman and Friesen 1969). This study aims to elicit leaked fast facial expressions and obtain a distribution of their duration, which we then use as evidence in an attempt to define and clarify the duration of micro-expressions.

According to Ekman, when a person tries to conceal his or her feelings, the true emotions would leak quickly and may be manifested as micro-expressions (Ekman and Friesen 1969). To elicit such facial expressions, the manipulations should induce participants to experience a high arousal and promote a strong motivation to disguise. In the early years, researchers constructed high-stakes situations to elicit micro-expressions, such as asking nurses to lie about what they saw in video episodes (Ekman and Friesen 1974), and constructing crime scenarios and opinion scenarios (Frank and Ekman 1997). In these

studies, the elicited leaked fast facial expressions were commonly confounded by other facial movements (mouth movements and conversational facial movements), therefore to some extent the coding process might be "contaminated" by these irrelevant facial actions. Recently, Porter and ten Brinke (2008) administered an experiment in which participants were required to disguise true facial expressions in three ways (neutralizing, masking, and simulating) when watching slides of emotional pictures. With this approach, very few micro-expressions were generated and they mainly emerged in the genuine, masking, and simulating conditions (all conditions included unwanted facial movements) but only one occurred in the neutralizing condition. To better understand the duration of micro-expressions, it is preferable to elicit sufficient "uncontaminated" leaked facial expressions which are not intermingled with other facial movements.

In Porter and ten Brink's (2008) study, emotional pictures were used to elicit emotions. In this study, we chose video episodes as the emotional stimuli. Video episodes have a relatively high degree of ecological validity (Gross and Robert 1995) and are usually better than pictures in term of emotional valence. Furthermore, video episodes are lasting and dynamic emotional stimuli, making inhibition more difficult.

To elicit relatively "uncontaminated" leaked fast facial expressions which were not surrounded by various unemotional facial movements (such as speaking), the neutralizing paradigm was employed in this study as the inhibition method, in which participants tried to inhibit any facial movements with great effort. Based on these elicited facial expressions, we will present the distribution of the durations of leaked fast facial expressions and then attempt to provide evidence to define the duration of micro-expressions.

Method

Materials

Video episodes were employed as the elicitation materials in this study. We downloaded 17 video episodes from the Internet, which were assumed to be highly positive or negative in valence. 20 participants rated the video episodes by choosing the one or two emotion words from a list and rated the intensity on a 7-point Likert Scale. If words belonging to a certain basic expression (e.g., happiness) were chosen by one-third of the participants or more, that emotion would be assumed as the main emotion(s) of the video episode. Table 1 shows participants' ratings on the 17 video episodes, including the main emotion for each episode, the rate of participants who felt such an emotion, and the mean score (intensity from 0 to 6 indicating "no such emotion" to "extremely strong").

Participants

Twenty-two adults (8 females, 14 males) participated in the experiment and had a mean age of 22.75 years ($SD = 2.01$). They all signed the informed consent and they had the right to quit the experiment at any time.

Procedure

Participants were instructed that the purpose of the study was to test their ability to control emotions, which was highly correlated to their social success. They were also told that their

Table 1 Participants' ratings on the 17 video episodes

Episode no.	Duration	Main emotion (s)	Rate of selection	Mean score (intensity)
1	2′52″	Happiness	0.69	3.27
2	1′18″	Happiness	0.71	3.60
3	51′	Happiness	0.70	3.14
4	1′32″	Happiness	0.64	4.43
5	1′28″	Disgust	0.81	4.15
6	1′7″	Disgust	0.69	4.18
7	1′35″	Disgust	0.78	4.00
8	1′34″	Disgust	0.81	3.23
9	1′56″	Fear	0.63	2.90
10	2′4″	Fear	0.67	2.83
11[a]	38″	–	–	–
12	2′25″	Disgust (fear)	0.60 (0.33)	3.78 (3.6)
13	1′31″	Sadness	0.71	4.08
14	1′57″	Sadness	1.00	5.00
15	1′57″	Anger (sadness)	0.69 (0.61)	4.33 (4.88)
16	1′37″	Anger	0.75	4.67
17	2′25″	Anger	0.94	4.93

[a] No single emotion word was selected by more than one-third of the participants

payments were directly related to their performance. If they showed any facial expressions while watching the video episodes, 5 Chinese Yuan (RMB) would be taken away from the payment as a punishment for each leakage. In addition, they were not allowed to turn away their eyes or head from the screen. These manipulations were employed to enhance participants' motivation to hide their genuine facial expressions and reduce irrelevant movements.

Each participant was seated in front of a 19-inch monitor. A camera (Point Grey GRAS-03K2C, with 60 frames per second) on a tripod was set behind the monitor to record the full-frontal face of the participant. The 17 video episodes were presented by the experimenter at a random order. The participant was told to closely watch the screen and maintain a neutral face. After each video episode, the participant was asked to rate the video episodes. When all the video episodes were finished, they watched their own recordings to label the unemotional facial movements and explained the possible emotions of some ambiguous facial expressions.

Data Analysis

Considering previous definitions on the duration of micro-expressions, 500 ms is the longest for its upper limit. Moreover, facial expressions with duration from 0.5 to 4 s were commonly considered as conventional ones (Ekman 2003; Matsumoto and Hwang 2011). Therefore, we focused on the facial expressions with the duration less than 500 ms. Two well-trained coders thoroughly inspected the recordings and selected the fast facial expressions. The coding procedures employed were listed as follows:

Step 1 The first step was a rough selection. This step was to reduce the quantity of to-be-analyzed facial expressions since it is time-consuming to code the duration in

precision. The coders played the recordings at half speed and roughly spotted the onset, apex, and offset frames and selected the facial expressions that lasted approximately less than 1 s. It was also noticed that some leaked fast facial expressions in our study were characterized as fast onset but slow offset. Because of their special temporal features (discussed in details later), these fast-onset facial expressions with onset phases (from the start to the apex) less than 500 ms (though the total duration is longer than 1 s) were also selected for later analysis.

Step 2 Habitual movements (such as blowing the nose, AU38) and other irrelevant movements [such as pressing the lips (AU14) when swallowing saliva, moving eyebrows (AU1 and/or AU2) because of changing focus of the eyes] were removed. These irrelevant facial movements were confirmed by the participants.

Step 3 By employing the frame-by-frame approach, the onset frames, apex frames, and offset frames were coded. The onset frame is the first frame which changes from the baseline (usually neutral facial expressions). The apex frame is the one that showed the full expression which had a highest intensity for this facial expression. The offset frame was the frame right before a facial movement returned to baseline (Hess and Kleck 2006; Hoffmann et al. 2010). To accurately spot the frame, coders typically had to repeatedly compare the subtle differences between adjacent frames around the onset, apex, and offset. Through extensive amount of work, the duration of these leaked fast facial expressions was calculated.

Step 4 Coded facial expressions lasting no longer than 500 ms (which is the longest upper limit in previous work) were included in the analysis. We tried to fit several probability density curves to the data in order to reveal the distribution of the duration of micro-expressions.

For the selected fast facial expressions, the coders also labeled action units (AUs) (Ekman et al. 2002a) for each sample independently and arbitrated their disagreements.

Results

The Results of the Total Duration of Micro-Expressions

Two participants were particularly successful in neutralizing expressions and did not show any facial expressions. Among more than 1,000 facial expressions recorded on camera, 245 leaked fast facial expressions lasting roughly less than 1 s were selected in Step 1. 109 facial expressions shorter than 500 ms were selected after Step 4 and the mean duration was calculated, $M = 313.91$ ms, $SD = 85.81$. The reliability coefficient equals the agreed range divided by full range of the frames for one sample.[1] The reliability coefficient of the two coders was .77 for all the samples. A histogram was generated to indicate the frequency of the facial expressions (y-axis) in various durations (x-axis). Considering the shape of the histogram, we tried models of Normal, Gamma, Weibull and Birnbaum–Saunders to fit the data and provided the distribution curves (see Fig. 1).

[1] For example, if the coder #1 coded one sample as from 100th to 120th frames and coder #2 as from 105th to 125th frames, then the agreed range is 15 and the total range is 25, the reliability coefficient is 0.6 for this case.

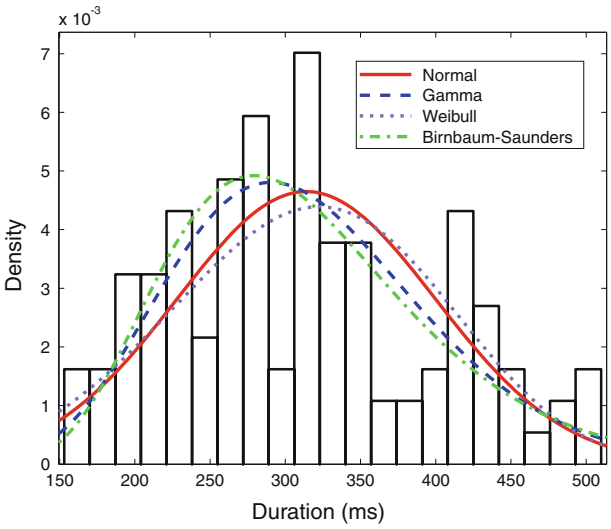

Fig. 1 The fitting distribution curves of four different models for the total duration of micro-expressions ($N = 109$). The x-axis represents durations of the selected micro-expressions; the y-axis shows probability density (relative likelihood for a certain duration to occur)

One-sample Kolmogorov–Smirnov (K–S) test was taken to compare the data to hypothesized continuous distribution. It is a form of minimum distance estimation that quantifies a distance between the empirical distribution function of the sample and the cumulative distribution function of the reference distribution. The null hypothesis is that the data has a distribution of that model, while the alternative hypothesis is that the data does not. The significance level alpha for the test was .05. K–S statistic (ksstat) indicates maximum vertical deviation between the standard curve and fitting curve. The best fit distribution is selected according to the minimum error produced. Results show that the four models were appropriate ($H = 0$) and Birnbaum–Saunders model is the best among them (ksstat = 0.0806) to fit the data.

To further evaluate the goodness of fit of the models, we used the Akaike's information criterion (AIC) (Akaike 1974) as well. It is grounded in the concept of information entropy; in effect offering a relative measure of the information lost when a given model is used to describe reality. AIC adds a penalty proportional to the number of model parameters to the log likelihood (LL) function in order to create a measure of the goodness of fit of a model. Results show Gamma model has smallest value for LL and AIC and thus best fit for the data (see Table 2).

The results of these two methods of testing the goodness of fit (ksstat and AIC) are inconsistent with each other. The Birnbaum–Saunders model and Gamma model have little difference in the values and both of them are quite good in fitting the data. Considering

Table 2 The results of K–S test and AIC under different fitting models

Model	H	p	ksstat	LL	AIC
Normal	0	0.2311	0.0979	−639.45	1,282.9
Gamma	0	0.4275	0.0824	−637.03[a]	1,278.1[a]
Weibull	0	0.1844	0.103	−640	1,284
Birnbaum–Saunders	0	0.455	0.0806[a]	−637.11	1,278.2

[a] The best choice in that test

K–S test is unstable for non-normal distributions, here we chose Gamma model to analyze the characteristics of the distribution.

The fitting curve shows that most of the samples are distributed in the center part, with only a few samples at two tails, which seems to be the boundaries for the duration. The significance level alpha is .05, meaning the confidence interval should cover 95 % of the curve area and the critical values at two tails of the curve can be considered as lower limit and upper limit of the duration. By calculating the Gamma inverse cumulative function, it is found that value of the left critical point is 169.07, while the value of the right critical point is 502.78. These results provide some evidence to define the lower limit and upper limit of the duration of micro-expressions.

The Results of Onset Duration of Micro-Expressions

There are some leaked facial expressions that have fast onset phase but very slow offset phase (some even remain in apex for seconds, thus much longer than 500 ms). When taking the total duration as the criteria, some fast-onset facial expressions would not be taken into account. However, these fast-onset facial expressions actually possesses the fundamental features for micro-expressions which is involuntary, fast initiated, and occurs when trying to conceal the emotions (Ekman and O'Sullivan 2006).

Therefore, we tried to calculate the onset duration and to see whether it might be a good indicator for micro-expression. The onset phases of the 109 samples defined as micro-expressions (with total duration less than 500 ms) were analyzed first. The reliability of the onset duration between two coders was .78, which is similar to that of the total duration. It was found that the onset duration was less than half of the total duration, $M = 139.91$, $SD = 50.05$. We used models of Normal, Gamma, Weibull, and Birnbaum–Saunders to fit the data and provided the distribution curves (see Fig. 2).

One-sample Kolmogorov–Smirnov test and Akaike's information criterion were also used to test the goodness of fit for the curves. K–S test shows that Normal model is not well fit for the data ($H = 1, p < 0.05$) and the other three were good ($H = 0, p > 0.05$). Among these three fitting curves, the results indicate Birnbaum–Saunders model has the smallest

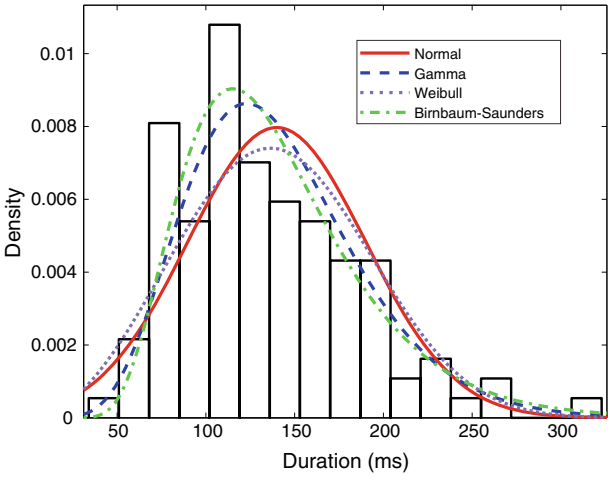

Fig. 2 The fitting distribution curves of different models for the onset duration of micro-expressions ($N = 109$). The *x*-axis represents durations of the selected micro-expressions; the *y*-axis shows probability density which means relative likelihood for a certain duration

Table 3 The results of Kolmogorov–Smirnov test and AIC under different fitting models

Model	*H*	*p*	ksstat	*LL*	*AIC*
Normal	1	0.0293	0.1375	−580.69	1,165.4
Gamma	0	0.1346	0.1097	−573.76	1,151.5
Weibull	0	0.0905	0.1176	−579.3	1,162.6
Birnbaum–Saunders	0	0.267	0.0945[a]	−573.09[a]	1,150.2[a]

[a] The best choice in that test

ksstat, LL and AIC statistic. It is indicated that Birnbaum–Saunders model best fit the data (see Table 3).

The results of these two methods of testing the goodness of fit are consistent with each other, showing that Birnbaum–Saunders is the best choice to fit the data. With this fitting curve, we are able to infer the upper limit of the duration of micro-expressions. The significance level alpha is .05, meaning confidence interval should cover 95 % of the curve area and the critical values at two tails of the curve can be considered as lower limit and upper limit of the duration. By calculating the Birnbaum–Saunders inverse cumulative function, it is found that the value of the left critical point is 65.97, while the value of the right critical point is 261.93. According to the fitting curve of the data, therefore, the lower limit is 65.97 ms and the upper limit is 261.93 ms.

The Quantity of Micro-Expressions with Different Criteria of Duration Limits

There were 109 micro-expressions with the total duration less than 500 ms. When micro-expressions were defined with onset duration less than 260 ms, 142 samples were selected, $M = 147.30$ ms, $SD = 49.01$ (Table 4). There were also 3 micro-expressions with onset duration longer than 260 ms (with the total duration no more than 500 ms), thus the total quantity of micro-expressions is 145 in our study.

There are 35 micro-expressions with onset duration less than 260 ms but total duration longer than 500 ms, such facial expressions consists of 24.1 % of the selected micro-expressions in our study. We tested whether the 35 "fast-onset-only" micro-expressions had the same distribution of onset duration as the 109 micro-expressions with total duration less than 500 ms. These onset durations were divided into 3 groups and Chi square tests were used for statistical analysis (Table 5), $\chi^2 = 30.64$, $p < 0.001$, indicating that the distributions of the onset duration for these two kinds of micro-expressions are different. It might suggest that the micro-expressions with total duration less than 500 ms are actually different from those with onset duration short than 260 ms but total duration longer than 500 ms.

Table 4 Descriptive statistics for total duration and onset duration of micro-expressions by different criteria

Upper limit	*N*	Total duration		Onset duration	
		M (ms)	*SD*	*M* (ms)	*SD*
500 ms (total duration)	109	313.91	85.81	139.91	50.05
200 ms (total duration)	12	187.5	14.43	87.5	20.26
260 ms (onset phase)	142	–	–	147.30	49.01

Table 5 Cross tabulations of counts for three groups of durations in two conditions

Types of micro-expressions	<150 ms	150–200 ms	>200 ms	Total
Onset duration <260 ms but total duration >500	8	17	10	35
All the micro-expressions in this study	63	37	9	109
Total	95	56	29	

According to Ekman's definition on the duration, "the classic 1/5 s" for the upper limit, 15 samples were found, $M = 188.1$ ms, $SD = 15.23$. According to the distribution curve of our samples, it seems inappropriate to define the upper limit of the duration as 200 ms. Such a disagreement may be due to different "types" of micro-expressions.

The Facial Actions of the Micro-Expressions

Apart from the duration, we also pay attention to the possible emotions leaked from the inhibited faces. The coders independently labeled AUs for each micro-expression and arbitrated the disagreement. The reliability coefficient was .83, as calculated by the formula (Ekman et al. 2002b):

$$\frac{\text{Number of AUs on which Coder 1 and Coder 2 agreed}}{\text{The total number of AUs scored by the two coders}} \times 2$$

Table 6 shows the AU-combinations of elicited 145 micro-expressions (total duration is no more than 500 ms or the onset duration is no more than 260 ms). We found labeling

Table 6 The AU-combination of elicited micro-expressions

Estimated emotion	AU-combination	*N*
Happiness	12	3
Disgust	4	9
	9	15
	4 + 9	11
	4 + 9 + 10	2
	9 + 10	5
	10	2
Sadness	1	4
	2 + 4	2
Anger	4	5
	4 + 9	3
Surprise	1 + 2	6
	2	3
Attention/interest	4	11
Tense/repression	4	4
	14	2
	14 + 15	2
	15	5
	17	2
	18	4

If the total number of AU combination appears only once or just on one participant's face, we do not present here

Table 7 The quantity of emotions presented in each video scene

Video scenes	The quantity of emotions presented								
	Happiness	Disgust (pain)[a]	Fear	Sadness	Anger	Surprise	Attention interest	Tense repression	Total
Happiness	4	5	–	–	–	6	2	1	18
Disgust	4	40	4	2	3	5	4	13	75
Fear	1	2	–	–	–	1	1	4	9
Sadness	–	2	–	3	–	–	–	1	6
Anger	–	8	–	5	5	–	5	14	37
Total	9	57	4	10	8	12	12	33	145

[a] Disgust and pain were put together because their AUs are usually similar in our study

exact emotions for these micro-expressions was difficult. First, many AU combinations haven't been consistently defined. For example, we do not know the exact emotion conveyed by AU7 + AU25 + AU12. Second, the facial movements were usually partial (only upper or lower part on the face) and with low intensity, thus the emotions are not definite. For example, AU 4 ("brow lowerer") can be found in anger, disgust, attention, or pain. Therefore, we labeled the emotions based on (1) the basic emotions' corresponding AU(s); (2) the emotion type for the video episodes and (3) The participants' self-report. Hence, we presented the *estimated* emotions. Further, the quantities of *estimated* emotions elicited in different emotion scenes were presented in Table 7.

In addition, we found very few facial expressions of happiness (AU12 or AU12 + AU6) among the micro-expressions. Actually, happy faces were easily found when the participants watched amusing video episodes but these facial expressions usually last much longer than 500 ms and thus does not fit the criteria of "fast".

Discussion

Reconsiderations on the Duration of Micro-Expression

First, it is important to state that we called these selected samples "leaked fast facial expressions" instead of micro-expressions because there is no clear and consistent definition of the duration of micro-expression. Since involuntary leakage and fast speed are two fundamental characteristics for micro-expression, we tried to select facial expressions with such properties and obtain their distributions. We observed that most of the samples gather in the middle of the curve while only a few lie at the tails. Based on the shape of the fitting curve, our work may help to find the upper limit and lower limit for the duration of micro-expression, or at least provide some evidence. By calculating the critical points that 95 % of the samples included between them, we accordingly are able to infer the lower limit and upper limit based on our data. The results showed that the upper limit of the duration of micro-expression is about 502 ms. This result echoes Matsumoto and Friesen's definition on the duration of micro-expression which is no more than 500 ms (Matsumoto and Hwang 2011). Thus, we consider 500 ms as an appropriate upper limit.

In our study, the fastest leaked facial expression was 166.67 ms. There could be some micro-expressions that are even shorter, thus we tried to find some evidence from

physiological studies to see the limit of the contraction time of the skeletal muscles. By electrically stimulating the articulatory muscles at the lips, it was found that the duration of the movement is about 100 ms (Ito et al. 2004). Considering all the facial muscles are skeletal muscles, it is thus possibly inferred that the duration of facial expressions cannot be shorter than 100 ms. Therefore, the lower limit of the duration micro-expression should between 100 ms and 166 ms.

We only found a few facial expressions ($n = 15$) fitting Ekman's definition of micro-expression. Similarly, another study revealed that micro-expressions occurred in only 2 % among nearly 700 genuine and falsified emotional expressions and sometimes apparently meaninglessly in genuine expressions (Porter and ten Brinke 2008). Researchers also found that most instances of emotional leakage lasted longer than 1/5th of a second, and frequently lasted for closer to a full second (Porter et al. 2012). Ekman's definition of duration requires more research to verify.

The lower limit of duration for micro-expression maybe questionable in Ekman's definition, for 1/25 s seems unimaginable for the speed of a facial expression. We did find some transient facial expressions that lasted less than 1/5 s, but none was shorter than 1/10 s. The physiological evidence doesn't support the claim either.

Though these results are inconsistent with Ekman's claim on the duration of micro-expressions, it is also important to notice that we used a different paradigm to elicit micro-expressions. In our study, participants were not in high-stakes situations as those in Ekman's study were. Moreover, a different repression strategy was employed by the participants to control their faces (neutralizing their faces instead of telling lies).

Valid and Reliable Onset Duration

A complete facial expression can be divided into onset phase, apex phase, and offset phase. When triggered by an emotion, the muscles have a rapid contraction in onset phase. This movement for micro-expressions is uncontrollable and indicating a leakage of genuine emotion. Sometimes such an emotional activation holds for a moment and appears as apex phase. On the other hand, for the offset phase the emotional arousal fades away and the muscles return to relaxed conditions, indicating the offset phase is actually not directly emotion-related. By close scrutiny, the onset phase has already included the fundamental features of micro-expressions which are involuntary leakage and fast speed. Onset duration thus may be valid to define micro-expressions.

There were some cases in which participants contracted certain facial muscles to the apex and didn't turn to the previous baseline immediately because participants were in tension and did not naturally loosen the muscles. Additionally, sometimes a facial expression merged into the next one, so it was difficult to label the offset frames. The offset duration has large variance but does not reflect the key features of micro-expressions. In comparison, the onset phase better represents the critical feature of the micro-expression and the duration is with smaller variance—most of the samples lie in the interval between 80 ms and 200 ms (which seems to be the rough time range for strong and involuntarily contraction). Therefore, onset phase might be more a suitable and reliable part to define micro-expressions.

It is therefore suggested that the onset phase alone can be an indicator for a micro-expression. The results showed 260 ms may be an appropriate upper limit for the onset duration of micro-expressions. Taking onset duration as a criterion to select micro-expression, the facial expressions with a total duration longer than 500 ms but with short enough onset duration (260 ms) would be also selected. With the considerations above, the definition of micro-expressions should be reconsidered, extended or modified.

The Shape and Emotion Type of the Micro-Expressions

The facial expressions elicited in our study were usually partial and had low intensity. Many micro-expressions in our study presented part of the AU-combination rather than the whole combination found in typical facial expressions, and in certain cases only a single AU presented. The intensity of the AUs may be as low as level A (see Ekman et al. 2002a, b for details on evaluating intensity). Such an appearance seems partly because of neutralization paradigm we used, which made participants inhibit their facial movements with strong intention and effort, and thus the leaked facial expressions were not obvious. Due to the characteristics of the shape, the emotional label for micro-expressions cannot be pinned down as easily as we do for the conventional facial expressions, which are fully stretched and without repression. We do not have a completely clear picture of corresponding emotion labels for these "fragmented AUs". Besides, some AUs posess meanings other than six typical emotions, such as those for repressing actions (e.g., AU 14 "dimpler" and AU 17 "chin raiser") which do not seem to represent an emotion themselves. Still, it is possible to obtain *estimated* emotion based on fragmented AUs, presented stimuli, and participants' self-reports.

The quantities of micro-expressions vary across different scenes. Most of the micro-expressions were found in negative scenes, especially in the disgusting ones. Disgusting stimuli seemed to easily elicit facial response or disgust-related AUs were just more easily triggered. Comparatively, micro-expressions of fear and happiness seldom appeared. In laboratory situations, with strong light surrounding them and a experimenter in the room, participants are not like to have a strong feeling of fear when seeing scary movie clips. As for micro-expressions of happiness, one may feel surprised as to why so few were elicited. Though happiness feelings were easily elicited when watching amusing video episodes, these elicited smiles or laughers are lasting facial expressions and do not fit the criteria of micro-expression. Thus, most of the elicited happy facial expressions were categorized as conventional facial expressions.

The Relationship Between the Micro-Expression and Emotion

More strongly felt emotion seemed to elicit more micro-expressions. Porter et al. (2012), selecting pictures from IAPS and ranking them by emotional valence, found stronger felt emotion elicit relatively more micro-expressions. Our study replaced pictures with video episodes as stimuli and observed an increase in elicited emotions. We believe this is mainly because the video episodes are higher in emotional valence, which makes inhibition more difficult.

The consistency between micro-expression and emotion may need further considerations. Because of the shape of micro-expression, the emotion it represents becomes ambiguous. Besides, there is always the possibility of some "noise", such as certain AUs just indicating the action of repression, which "contaminated" the expression of repressed emotion. Moreover, it becomes increasingly difficult that different people may develop different ways of repression.

Our observations showed that participants were not able to repress the outlet of the emotion and thus the micro-expressions appeared. We are not sure whether there should be other mechanisms of generating micro-expressions. Is it possible that micro-expressions occur when participants do not react *fast* enough to repress the outlet? If it is, such micro-expressions may appear in a different way.

Conclusions and Future Work

To provide evidence to define micro-expression by its duration, we conducted the study to elicit leaked facial expressions and selected the fast leaked ones. The distribution of the duration of the leaked fast facial expressions was described. Based on the fitting curve of the distribution, the duration boundaries of the micro-expressions are given, namely around 500 ms for upper limit and about 170 ms for the lower limit. Onset phase is also considered as a good indicator to define micro-expressions, with the upper limit around 260 ms and the lower limit about 65 ms. Our results were obtained by employing neutralization paradigm and were analyzed in a different approach, thus the temporal features and action units of the micro-expressions described here should be reconsidered before applying to other situations.

Various questions remain unclear and should be further discussed. First, the micro-expressions elicited in different paradigms (e.g., telling lies or masking facial expressions) may have different appearances, whether in temporal features or facial actions. Second, the associations between facial movements and felt emotions haven't been clearly defined because of the partial presentation of micro-expressions. Third, most of the micro-expressions found in our study were partial movements, which are also considered as subtle expression in some situations (Warren et al. 2009). Thus, the boundary between micro-expression and subtle expression seems ambiguous. Fourth, different types of micro-expressions may have their different distribution of durations. According to our observation, expressions of happiness usually last longer than disgust, though participants try to inhibit with the same effort. Accordingly, different AUs may have different onset/offset speed, a topic that requires further study.

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