Review in Psychology Research
December 2012, Volume 1, Issue 1, PP.20-31

Generalization Effect of Conditioned Sadness: An Innovation of the Approach to Elicit Implicit Sadness

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Abstract

Event-related potentials (ERPs) were recorded to explore electrophysiological correlates of conditioned sadness and happiness generalization processing in a classical conditioning paradigm when subjects performed a simple number estimation task during post-conditioning phase. Three emotion conditions (happy, neutral, and sad) were examined, each of which contained two phases: a conditioning phase and a post-conditioning phase. During conditioning phase of each emotion condition, we presented 56 three-digit-numbers (i.e. conditioned numbers) which were paired respectively with 56 facial expressions containing one emotion one by one; participants were instructed to attempt, to the best of their ability, to study and remember the number while ignoring the facial expression as much as possible. During post-conditioning phase of each emotion condition, we presented three kinds of three-digit-numbers [i.e. 56 conditioned numbers, 56 generalized numbers, and 56 control numbers] one by one; participants were instructed to judge whether the figure had been presented during conditioning phase or not. Our results showed that (1)the three-digit-numbers [i.e. Sad Generalized Numbers] which might contain the generalized conditioned sadness elicited a more negative ERP component (P300–600) than did the three-digit-numbers [i.e. Neutral Generalized Numbers] which might be neutral ($P < 0.05$); and (2) the three-digit-numbers [i.e. Happy Control Numbers] which might contain the biased attention toward novel stimuli induced by positive stimuli elicited a more negative ERP component (P450–750) than did the three-digit-numbers [i.e. Neutral Control Numbers] which might be neutral ($P < 0.05$). Thus, it is suggested that P300–600 may constitute the brain indices of generalized conditioned sadness. We discuss whether the generalized conditioned sadness elicited by Sad Generalized Numbers could be implicit. Whether P450–750 is related to the neural correlates of the biased attention toward novel stimuli elicited by positive stimuli is also discussed.

Keywords: Classical Conditioning Paradigm; Generalized Conditioned Sadness; Event-Related Potential (ERP); P300-600/ P450-750; Broaden-And-Build Theory

I. INTRODUCTION

Conditioned fear and its generalization were demonstrated by Watson et al. almost a century ago (Watson et al., 1920). In their studies, John Watson and Rosalie Rayner claimed to have conditioned a baby boy, Albert, to fear a white rat. Most importantly, they reported that the baby's fear generalized to other white objects (Watson et al., 1920). This strikingly powerful research continues to exert influence today. However, happiness and sadness, two of the six basic emotions of mankind (Ekman, 1992; Duan et al., 2010), have not been examined with respect to the timing of conditioned sadness and happiness generalization. Based on Watson et al.'s influential studies, we suggested the rationale of our study as follows:

The three-digit numbers were neutral stimuli; the sad facial expressions were unconditioned stimuli. During conditioning phase of our experiment, we presented participants with the three-digit numbers and the sad facial

expressions at the same time. After the presentation of a total of 56 ×5 pairings of the three-digit numbers and the sad facial expressions, the three-digit numbers were presented to participants, without the sad facial expressions. Therefore, we suggested that (1) during conditioning phase a sad response should have been conditioned to the three-digit numbers that had been neutral to the participants before the conditioning phase (thus we named them Sad Conditioned Numbers), and (2) during post-conditioning phase this learned sadness would transfer [in psychological terms, this transfer is referred to as generalization] to other similar three-digit numbers (thus we named them Sad Generalized Numbers); in other words, the participants would show sadness to Sad Generalized Numbers which contained the same clue number "7" with Sad Conditioned Numbers. The rationale could apply to the happy condition and neutral condition also.

Based on the rationale, firstly, we supposed that during conditioning phase of neutral condition, the neutral mood of the neutral facial expressions would be conditioned to Neutral Conditioned Numbers [i.e., the three-digit numbers (with containing "5" but without containing "2" and "7") which were associated with neutral facial expressions during conditioning phase]. Then during post-conditioning phase of neutral condition, the learned neutral mood would generalize to the similar new three-digit numbers with the same "clue number"(i.e., 5) - Neutral Generalized Numbers [i.e., the three-digit numbers (with containing "5" but without containing "2" and "7") which were only presented during post-conditioning phase of neutral condition]. Neutral Control Numbers [i.e., the three-digit numbers (without containing "2" and "5" and "7") which were only presented during post-conditioning phase of sad condition], Neutral Conditioned Numbers, and Neutral Generalized Numbers were presented during post-conditioning phase in neutral condition.

TABLE 1 SOME EXAMPLES OF NEUTRAL CONDITIONED NUMBERS

315	531	513
154	451	415
356	536	563

[Note: In the experiment, the color of all number stimuli was green on the black background.]

TABLE 2 SOME EXAMPLES OF SAD CONDITIONED NUMBERS

317	731	713
174	471	417
376	736	763

[Note: In the experiment, the color of all number stimuli was green on the black background.]

Secondly, we supposed that during conditioning phase of sad condition, the sadness of the sad facial expressions would be conditioned to Sad Conditioned Numbers [i.e., the three-digit numbers (with containing "7" but without containing "2" and "5") which were associated with sad facial expressions during conditioning phase]. Then during post-conditioning phase of sad condition, the learned sadness would generalize to the similar new three-digit-numbers with the same "clue number"(i.e., 7) -Sad Generalized Numbers [i.e., the three-digit numbers (with containing "7" but without containing "2" and "5") which were only presented during post-conditioning phase of sad condition]. Sad Control Numbers [i.e., the three-digit numbers (without containing "2" and "5" and "7") which were only presented during post-conditioning phase of sad condition], Sad Conditioned Numbers, and Sad Generalized Numbers were presented during post-conditioning phase in sad condition.

Thirdly, we supposed that during conditioning phase of happy condition, the happiness of the happy facial expressions would be conditioned to Happy Conditioned Numbers [i.e., the three-digit numbers (with containing "2" but without containing "5" and "7") which were associated with happy facial expressions during conditioning phase], then during post-conditioning phase of happy condition, the learned happiness would generalized to the similar new three-digit numbers with the same "clue number" (i.e., 2) -Happy Generalized Numbers [i.e., the three-digit numbers (with containing "2" but without containing "5" and "7") which were only presented during post-conditioning phase of happy condition]. Happy Control Numbers [i.e., the three-digit numbers (without containing "2" and "5" and "7") which were only presented during post-conditioning phase of sad condition], Happy Conditioned Numbers, and Happy Generalized Numbers were presented during post-conditioning phase in happy condition.

TABLE 3 SOME EXAMPLES OF HAPPY CONDITIONED NUMBERS

312	231	213
124	421	412
326	236	263

[Note: In the experiment, the color of all number stimuli was green on the black background.]

To sum up, we hypothesized for our study that (1) the neural basis for processing of generalized conditioned sadness induced by Sad Generalized Numbers and of neutral mood induced by Neutral Generalized Numbers might be different, and (2) the neural basis for processing of generalized conditioned happiness induced by Happy Generalized Numbers and of neutral mood induced by Neutral Generalized Numbers might be different.

II. METHODS

A. Participants

As paid volunteers, 16 healthy undergraduate students (average age 20.75 years, range 18-24; eight females and eight males) from xx University (xx) in xx participated in the study. We obtained appropriate ethics committee approval for this research, and all subjects gave written informed consent. All subjects were right-handed, had no history of current or past neurological or psychiatric illness or drug abuse, and had normal or corrected-to-normal vision. All subjects were ignorant regarding the purpose of the experiment.

B. Stimuli and procedure

Three emotion conditions (happy, neutral, and sad) were examined, each of which contained two phases: a conditioning phase and a post-conditioning phase. Eight participants chosen randomly undertook the experimental trial in the order of the happy condition first, neutral condition second, and sad condition last. The other eight participants undertook the experimental trial in reverse order: sad condition first, neutral condition second, and happy condition last. The interval of time between adjacent emotion conditions was 120 sec. All participants were seated in a semi-dark room facing a screen placed at a distance of 60 cm from their eyes, and were instructed to avoid blinking and eye movement of any sort and to keep their eyes fixated on the monitor during task performance.

(1) The conditioning phase

Because it is commonly recognized that facial expression is an index of emotion (Bunce et al., 1999) whereas three-digit numbers are often regarded as emotionless, we presented 56 three-digit-numbers (i.e. conditioned numbers) which were paired respectively with 56 facial expressions containing one emotion one by one during conditioning phase of each emotion condition .

All three-digit number stimuli were displayed in Song Ti No. 20, and stimulus angle was 2.5° (horizontal) × 1.4° (vertical). Stimuli were displayed in the center of a 17-inch screen.

During conditioning phase of each emotion condition, Participants were instructed to attempt, to the best of their ability, to study and remember the numbers while ignoring facial expressions as much as possible (implicit emotion task 1).

To eliminate the number size effect and ensure taking the same digit for the emotion rule out direct stimulus effects on different responses, the emotionality, complexity and familiarity of the ten single numbers (i.e. from 0 to 9) were evaluated in a rating study, in which 44 participants were asked to judge the emotionality (3 scales: sad, neutral, happy), complexity (3 scales: simple, moderate, complex), and familiarity (3 scales: familiar, moderate, strange) of the ten single numbers respectively. According to the results, the numbers 2, 5, and 7 (emotionality: neutral; complexity: moderate; familiarity: familiar) were selected as "clue numbers" for our experiment.

All of the affective face pictures used in our study were selected from the standardized Chinese Affective Picture System (CAPS) because previous studies indicated that emotional facial expressions can cause participants to experience emotions with the same emotion value as the emotional facial expressions (e.g., Reinders et al., 2006; Rodrigues et al., 1995;

Wen et al., 2008). CAPS is validated and standardized. Standardized CAPS was developed in a laboratory of mental health at the Chinese Academy of Sciences to avoid cultural bias of emotional inducement found in Chinese subjects when IAPS is used. The CAPS introduced a number of pictures characterized by oriental natural scenes and faces. The CAPS procedure follows that established by IAPS. In the pretest for this system, 46 Chinese university students were chosen to rate the valence, arousal, and dominance of 852 pictures by exploring their self-report in a nine-point rating scale. The pretest showed that CAPS could be reliable across individuals in emotional inducement (the between-subject reliability scores were 0.982 for valence and 0.979 for arousal). More details regarding CAPS are presented in Bai et al. (Bai et al., 2005). Besides, we selected sad and happy face pictures with different valence parameters ($P < 0.05$) for the current study (Yuan et al., 2009).

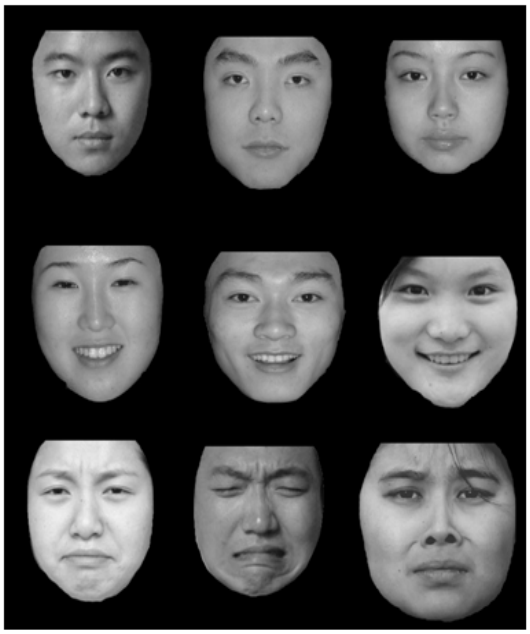


FIG.1 SOME EXAMPLES OF THE CAPS. THE FIRST LINE CONTAINED THREE NEUTRAL FACES. THE SECOND LINE CONTAINED THREE HAPPY FACES. THE THIRD LINE CONTAINED THREE SAD FACES

Each trial during conditioning phase was initiated by a 300-ms presentation of a small black cross on a white computer screen. Next, a blank screen, the duration of which varied randomly between 500 and 1500 ms, was followed by the onset of a "facial expression + three-digit number" stimulus, the duration of which was fixed at 800 ms; thus, presentation of the stimulus picture during this phase was terminated after 800 ms (Fig. 2).

(2) The post-conditioning phase

When participants completed the conditioning phase of one emotion condition, they began post-conditioning phase of the same emotion condition two minutes later. For each emotion condition, only the ERPs of post-

conditioning phase were recorded and analyzed.

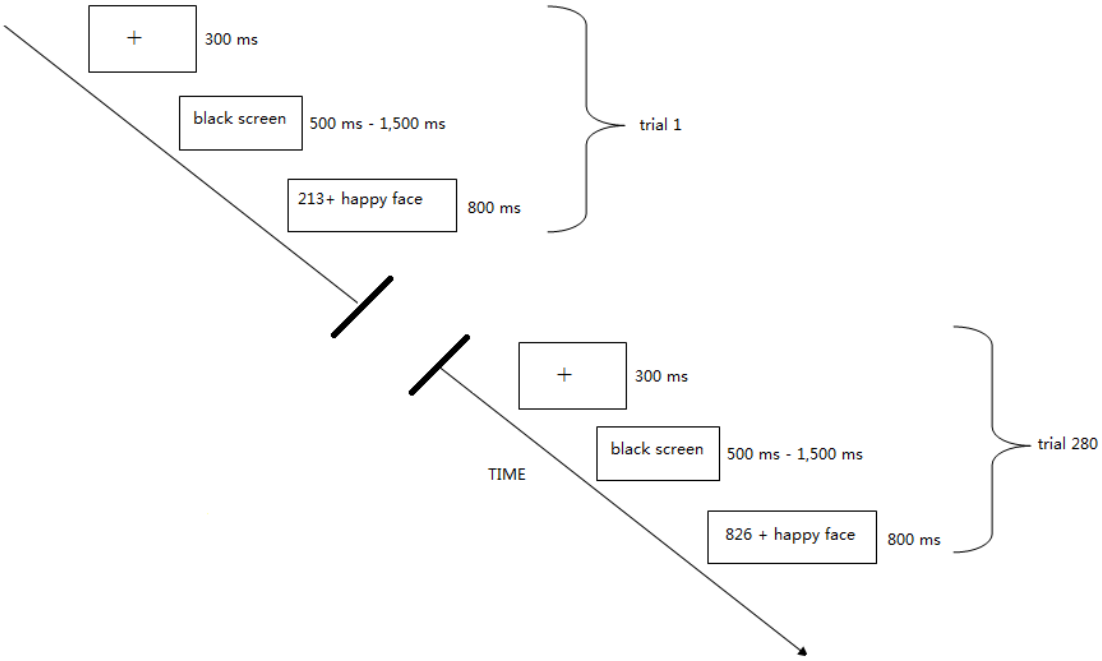


FIG.2. SEQUENCE OF EVENTS DURING CONDITIONING PHASE IN HAPPY CONDITION. FIXATION CROSS, BLACK SCREEN, AND THREE-DIGIT NUMBER PAIRED WITH SAD FACIAL EXPRESSION APPEARED IN WHITE ON A BLACK BACKGROUND. 56 HAPPY CONDITIONED NUMBERS RESPECTIVELY PAIRED WITH 56 DIFFERENT HAPPY FACIAL EXPRESSIONS. THE ABOVE-MENTIONED EXPERIMENTAL PROCEDURE FOR HAPPY EMOTION CONDITION WAS REPEATED FIVE TIMES, THUS, 280 "FACIAL EXPRESSION + THREE-DIGIT NUMBER" STIMULI WERE PRESENTED IN TOTAL DURING CONDITIONING PHASE OF HAPPY CONDITION. THIS SEQUENCE OF EVENTS DURING CONDITIONING PHASE IS FIT FOR NEUTRAL CONDITION AND SAD CONDITION ALSO

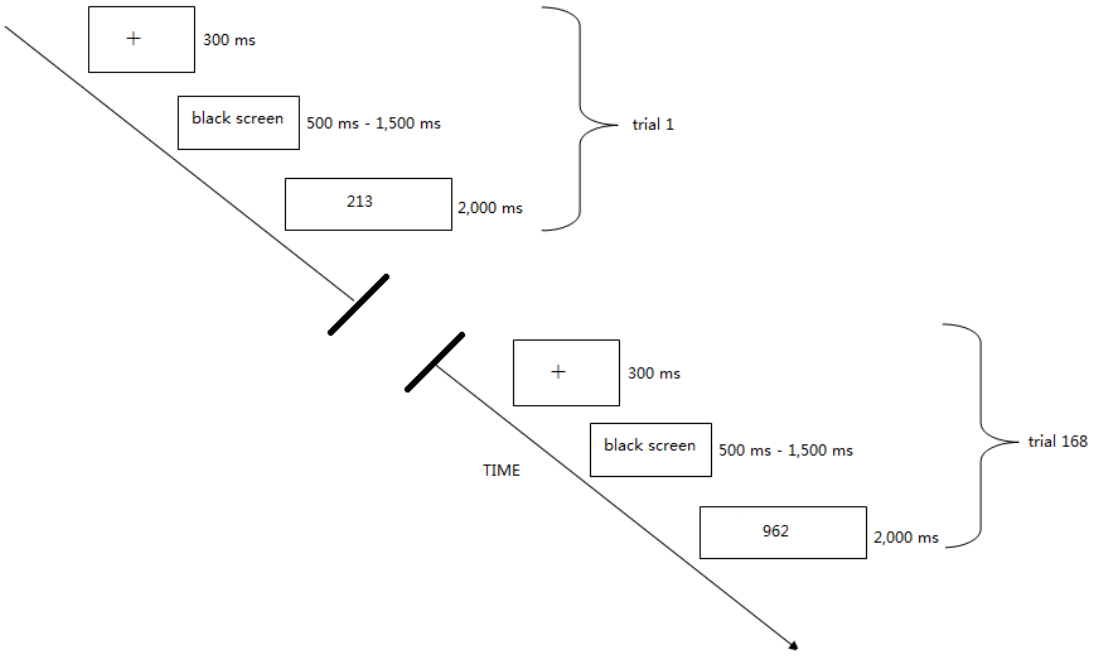


FIG.3. SEQUENCE OF EVENTS DURING POST-CONDITIONING PHASE IN HAPPY CONDITION. FIXATION CROSS, BLACK SCREEN, AND THREE-DIGIT NUMBER APPEARED IN WHITE ON A BLACK BACKGROUND. 56 HAPPY CONDITIONED NUMBERS, 56 HAPPY GENERALIZED NUMBERS, AND 56 HAPPY CONTROL NUMBERS WERE PRESENTED FOR ONE TIME RANDOMLY. THUS, 168 THREE-DIGIT-NUMBER STIMULI WERE PRESENTED IN TOTAL DURING POST-CONDITIONING PHASE OF HAPPY CONDITION. THIS SEQUENCE OF EVENTS DURING POST-CONDITIONING PHASE IS FIT FOR NEUTRAL CONDITION AND SAD CONDITION ALSO

Each trial during post-conditioning phase was initiated by a 300-ms presentation of a small black cross on a white computer screen. Next, a blank screen, the duration of which varied randomly between 500 and 1500 ms, was

followed by the onset of a figure picture stimulus (Fig.3). The duration of each presentation of figure picture stimuli during this phase was 2000 ms.

During post-conditioning phase of each emotion condition, we presented three kinds of three-digit-numbers [i.e. conditioned numbers, generalized numbers, and control numbers, see page3-4]; participants were instructed to judge whether the figure had been presented during conditioning phase or not and press the "1" key on the keyboard (as accurately and quickly as possible) if they judged that the figure had been presented during conditioning phase, or press the "2" key if they judged that the figure had not been presented during conditioning phase (implicit emotion task 2). The stimulus picture during post-conditioning phase was terminated by key pressing or was terminated after 2000 ms had elapsed. Therefore, each participant was informed that his or her responses must be made within 2000 ms. Immediately following post-conditioning phase of the last emotion condition for each participant, we surveyed his or her self-reported affective state during this phase using investigating question 1 - "Did you have any type of emotional experiences during the second phase?" Then, participants were probed for their ability to detect the regularities of the three-digit numbers in our present study by answering investigating question 2 - "Did you notice any regularities in the three-digit numbers during the first phase?" First, to ensure that participants consistently interpreted the two investigating questions in the desired fashion, the experimenters explained the meaning of the two questions to the participants after the ERPs study had finished and before the two investigation questions were presented. Therefore, the investigation would not proceed unless the participants informed the experimenters that they had grasped the meaning of the two questions with a clear understanding of what qualified as "emotional experience" and "regularities" . Second, experimenters instructed the participants to believe that any of their would-be answers of the two open investigating questions would be acceptable because the answers would be neither right nor wrong. Answers to the two questions were recorded accurately and rapidly by the experimenters.

C. Electrophysiological recording and analysis

Brain electrical activity was recorded from 64 scalp sites using tin electrodes mounted in an elastic cap (Brain Products, Gilching, Germany), with an average reference electrode on the left and right mastoids and a ground electrode on the medial frontal aspect. Vertical electrooculograms (EOGs) were recorded supra- and infra-orbitally at the left eye. Horizontal EOG was recorded from the left versus right orbital rim. All interelectrode impedance was maintained below 5 kΩ. EEG and EOG were amplified using a 0.05–80 Hz band pass and continuously sampled at 500 Hz/channel for offline analysis. Eye movement artifacts (blinks and eye movements) were rejected offline. Trials with EOG artifacts (mean EOG voltage exceeding ± 80 μV) and those contaminated with artifacts due to amplifier clipping, bursts of electromyographic activity, or peak-to-peak deflection exceeding ± 80 μV were excluded from averaging.

In the current study we analyzed the ERPs elicited by the 6 kinds of new three-digit-numbers (i.e. 3 kinds of generalized numbers and 3 kinds of control numbers). The averaged epoch for ERPs was 1200 ms, comprising 1000 ms post-stimulus and 200 ms pre-stimulus. As observed in the grand averaged waveforms at F2 and FC2 (see Figs. 4 and 5), the ERPs elicited by Sad Generalized Numbers, Neutral Generalized Numbers, and the ERPs elicited by Happy control Numbers, Neutral Control Numbers were clearly distinct from each other.

Difference waves were obtained by subtracting the averaged ERPs of Sad Generalized Numbers from the averaged ERPs of Neutral Generalized Numbers and subtracting the averaged ERPs of Happy Control Numbers from the averaged ERPs of Neutral Control Numbers; these differences were prominent over the frontal scalp regions. Thus, the following six electrode sites were selected for statistical analyses: Fz, F1, F2, FCz, FC1, and FC2. Analysis of variance (repeated-measures ANOVA) factors were emotion value (happy emotion value, neutral emotion value, and sad emotion value), number type (generalized numbers and control numbers), and electrode site (Fz, F1, F2, FCz, FC1, and FC2). Therefore a 3×2×6 ANOVA (happy emotion value vs. neutral emotion value vs. sad emotion value×generalized numbers vs. control numbers×Fz vs. F1 vs. F2 vs. FCz vs. FC1 vs. FC2) was conducted. For all analyses, the P-value was corrected for deviations according to Greenhouse-Geisser.

III. RESULTS

A. Behavioral data

Firstly, the averaged ACC for the nine kinds of three-digit-numbers (i.e. 3 kinds of conditioned numbers, 3 kinds

of generalized numbers, and 3 kinds of control numbers) in happy condition was 63.29+±17.30%; the averaged ACC in neutral condition was 65.28±17.11%; the averaged ACC in sad condition was 62.10±17.93%. Secondly, all 16 participants answered "No" to investigating question 1 and 2. Thirdly, the mean accuracy rate (ACC) and the mean response time (RT) for the 6 kinds of new three-digit-numbers presented in the simple number judgment task are shown in Table 4.

TABLE 4 THE MEAN ACCURACY RATE (ACC) AND THE MEAN RESPONSE TIME (RT) FOR HAPPY GENERALIZED NUMBERS, SAD GENERALIZED NUMBERS, NEUTRAL GENERALIZED NUMBERS, HAPPY CONTROL NUMBERS, SAD CONTROL NUMBERS, AND NEUTRAL CONTROL NUMBERS DURING POST-CONDITIONING PHASE

	ACCs (%)	RTs (ms)
Sad Generalized Numbers	37.29±20.40%	977.64±275.55
Neutral Generalized Numbers	35.24±21.66%	973.41±197.49
Happy Generalized Numbers	44.41±19.86%	969.13±191.60
Sad Control Numbers	81.06±18.10%	836.62±182.66
Neutral Control Numbers	84.47±15.43%	829.45±180.67
Happy Control Numbers	75.35±18.25%	844.34±151.63

Repeated-measures ANOVA for ACCs showed that the main effect of number type (i.e. generalized numbers and control numbers) was significant [$F(1,15) = 20.198$, $P < 0.05$], the interaction effect of emotion value (i.e. happy emotion value, sad emotion value, and neutral emotion value) and number type was not significant [$F(2,14) = 0.779$, $P > 0.05$]. Furthermore, pairwise comparison showed that the difference between Sad Generalized Numbers and Sad Control Numbers, Neutral Generalized Numbers and Neutral Control Numbers, and the difference between Happy Generalized Numbers and Happy Control Numbers were all significant ($P < 0.05$). Repeated-measures ANOVA for ACCs showed that the main effect of emotion value was not significant [$F(2, 14) = 0.181$, $P > 0.05$].

Repeated-measures analysis of variance (ANOVA) for RTs showed that the main effect of number type was significant [$F(1, 15) = 84.141$, $P < 0.05$]. Further, the interaction effect of emotion value and number type was significant [$F(2, 14) = 4.278$, $P < 0.05$]. Pairwise comparison showed that the difference between Sad Generalized Numbers and Sad Control Numbers, Neutral Generalized Numbers and Neutral Control Numbers, and the difference between Happy Generalized Numbers and Happy Control Numbers were all significant ($P < 0.05$). However, repeated-measures ANOVA for RTs showed that the main effect of emotion value was not significant [$F(2, 14) = 0.397$, $P > 0.05$].

B. Electrophysiological scalp data

We did not compare the difference between Sad Conditioned Numbers and Sad Generalized Numbers to avoid the "old/new effect" (Michael et al., 1994). Besides, Sad Conditioned Numbers elicited a more negative amplitude significantly than Neutral Conditioned Numbers ($P < 0.05$) in the time window 650ms-750ms however this effect did not exist between Happy Conditioned Numbers and Neutral Conditioned Numbers ($P > 0.05$). Therefore, we suspect that sadness might be conditioned more easily than happiness.

Grand-average ERP waveforms (see Figs.4 and 5) showed the following spatiotemporal distribution for the ERPs data. Figure 4 and 5 displays the event-related potential results in the frontal scalp electrodes for the six new kinds of three-digit numbers. A negative component, N100-150, and a positive component, P2, were obtained for the six presentation formats of three-digit numbers peaking maximally at the Fz, F1, FCz, FC1, F2 and FC2 electrodes (see Fig.3, Fig.4). Thus a 3(happy emotion value, neutral emotion value, and sad emotion value)×2(generalized numbers and control numbers)×6(Fz vs. F1 vs. F2 vs. FCz vs. FC1 vs. FC2) repeated measures ANOVA was conducted.

The ANOVA results showed that there were no main effects of emotion value or number type on the amplitude and latency of N100-150. The main effect of electrode sites on the amplitude and latency of N100-150 were not significant

(P > 0.05). The interaction effect of emotion value and number type of N100-150 was not significant (P > 0.05).

We also did not identify the main effects of emotion value or number type for the amplitude and latency of P2. The main effect of electrode sites on the amplitude and latency of P2 were not significant ((P > 0.05). The interaction effect of emotion value and number type of P2 was not significant (P > 0.05).

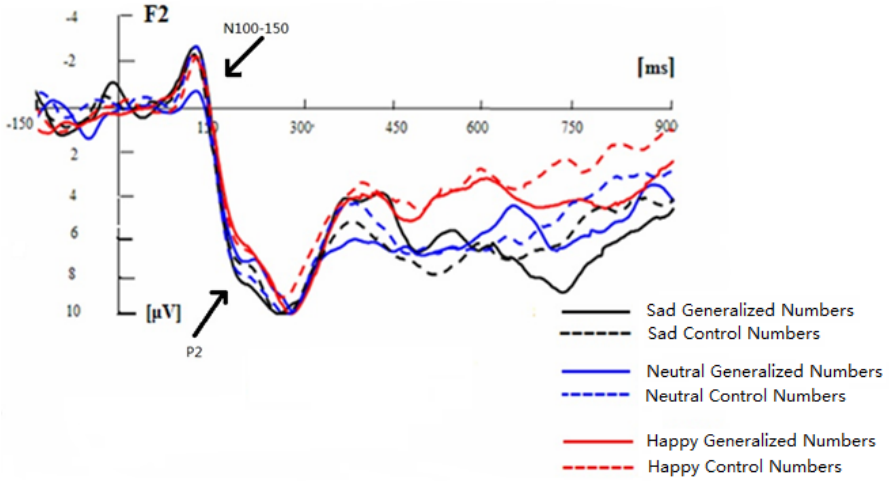


FIG.4. GRAND AVERAGE ERPS TO SAD GENERALIZED NUMBERS, NEUTRAL GENERALIZED NUMBERS, HAPPY GENERALIZED NUMBERS, SAD CONTROL NUMBERS, NEUTRAL CONTROL NUMBERS, AND HAPPY CONTROL NUMBERS AT F2

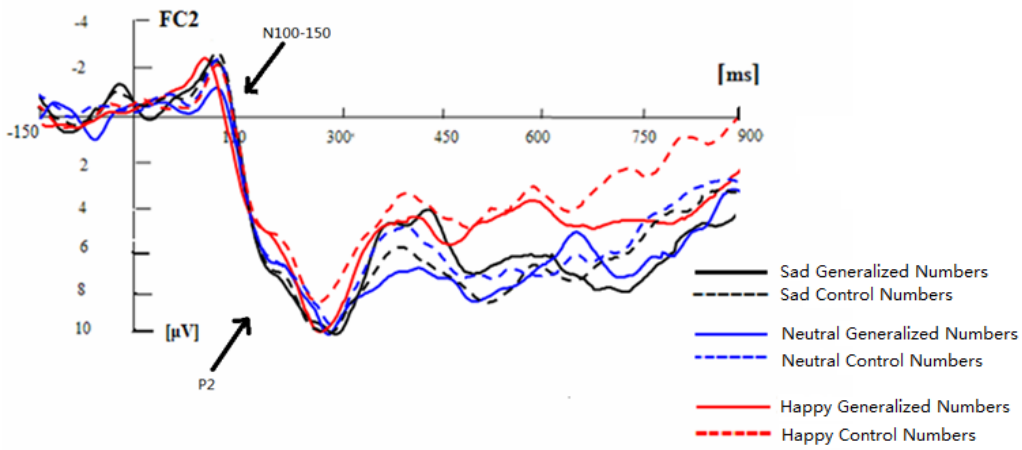


FIG.5. GRAND AVERAGE ERPS TO SAD GENERALIZED NUMBERS, NEUTRAL GENERALIZED NUMBERS, HAPPY GENERALIZED NUMBERS, SAD CONTROL NUMBERS, NEUTRAL CONTROL NUMBERS, AND HAPPY CONTROL NUMBERS AT FC2

In addition, Sad Generalized Numbers and Neutral Generalized Numbers elicited a late positive component in the time windows of 300-450 ms and 450-600 ms (Figs.6 and 7). Besides, Happy Control Numbers and Neutral Control Numbers elicited a late positive component in the time windows of 450-600 ms and 600-750 ms (Figs.8 and 9). Therefore, mean amplitudes in the time windows of 300-450, 450-600, and 600-750 ms were analyzed using a 3(happy emotion value, neutral emotion value, and sad emotion value)×2(generalized numbers and control numbers) ×6(Fz vs. F1 vs. F2 vs. FCz vs. FC1 vs. FC2) repeated measures ANOVA.

The main effect of emotion value in the time window of 300-450 ms was not significant [F (2, 14) = 1.073, P > 0.05]. Additionally, the main effect of number type was not significant [F (1, 15) = 0.153, P > 0.05]. However, the interaction effect of emotion value and number type was significant [F (2, 14) = 5.355, P < 0.05]. Pairwise comparison showed that Sad Generalized Numbers elicited a more negative ERP component than did Neutral Generalized Numbers in the time window of 300-450 ms (P < 0.05) (Fig. 6). The main effect of electrode sites in the time window of 300-450 ms was significant [F (5, 15) =4.222, P< 0.05].

The main effect of emotion value in the time window of 450-600 ms was significant [F (2, 14) = 6.445, P < 0.05], while the main effect of number type was not significant [F (1, 15) = 0.988, P > 0.05]. The interaction effect of emotion value and number type was not significant [F (2, 14) = 2.826, P > 0.05]. Pairwise comparisons showed that in the time window of 450-600 ms, (1) Sad Generalized Numbers elicited a more negative ERP component than did

Neutral Generalized Numbers (P < 0.05) (Fig. 7), and (2) Happy Control Numbers elicited a more negative ERP component than did Neutral Control Numbers (P < 0.05) (Fig. 8). The main effect of electrode sites in the time window of 450-600 ms was not significant [F (5, 15) =2.692, P> 0.05].

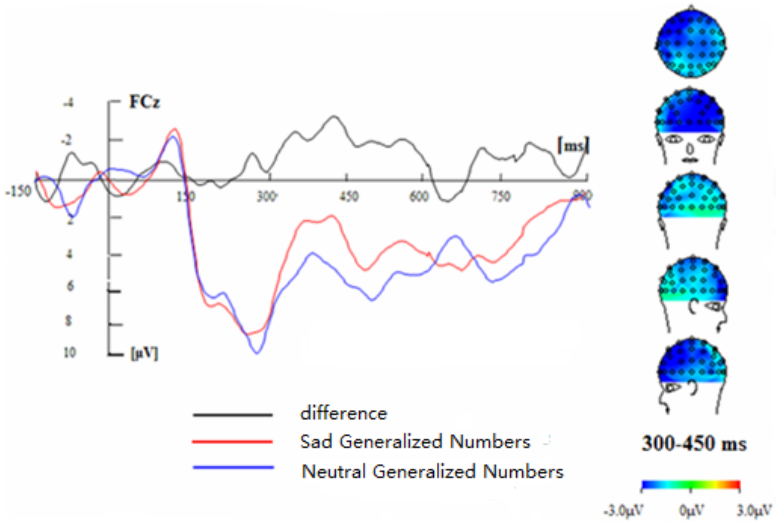


FIG.6. GRAND AVERAGE ERPS TO SAD GENERALIZED NUMBERS, NEUTRAL GENERALIZED NUMBERS, AND THE DIFFERENCE WAVE (SAD GENERALIZED NUMBERS–NEUTRAL GENERALIZED NUMBERS) AT FCZ IN THE TIME WINDOW OF 300-450 MS

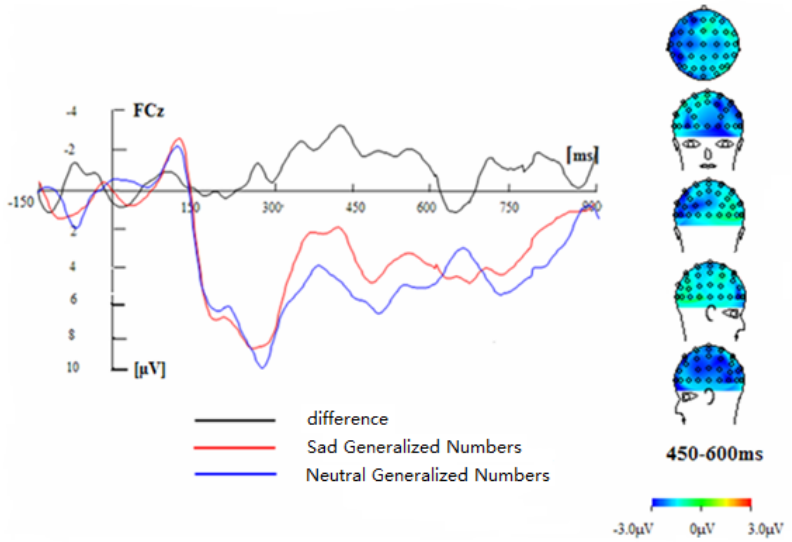


FIG.7. GRAND AVERAGE ERPS TO SAD GENERALIZED NUMBERS, NEUTRAL GENERALIZED NUMBERS, AND THE DIFFERENCE WAVE (SAD GENERALIZED NUMBERS–NEUTRAL GENERALIZED NUMBERS) AT FCZ IN THE TIME WINDOW OF 450-600 MS

The main effect of emotion value in the time window of 600-750 ms was significant [F (2, 14) = 3.636, P = 0.05]. However, the main effect of number type was not significant [F (1, 15) = 0.111, P > 0.05]. The interaction effect of emotion value and number type was not significant [F (2, 14) = 0.013, P > 0.05]. Pairwise comparisons showed that Happy Control Numbers elicited a more negative ERP component than did Neutral Control Numbers (P < 0.05) in the time window of 600-750 ms (Fig. 9). The main effect of electrode sites in the time window of 600-750 ms was not significant [F (5, 15) =1.850, P> 0.05].

IV. CONCLUSIONS

In the present study, we used ERPs to explore the electrophysiological correlates of generalized conditioned happiness and generalized conditioned sadness induced by stimuli presented above threshold in a classical conditioning paradigm. Our results showed that (1) Sad Generalized Number, which induce generalized conditioned sadness, elicited a more negative ERP component (P300-600) than did Neutral Generalized Numbers, which induced neutral mood (P < 0.05) between 300-600 ms; (2) Happy Control Numbers elicited a more negative ERP component (P450-750) than did Neutral Control Numbers (P < 0.05) between 450-750 ms; and (3) All participants' self-reported

affective states were emotionless. Below we discuss the implications of these findings.

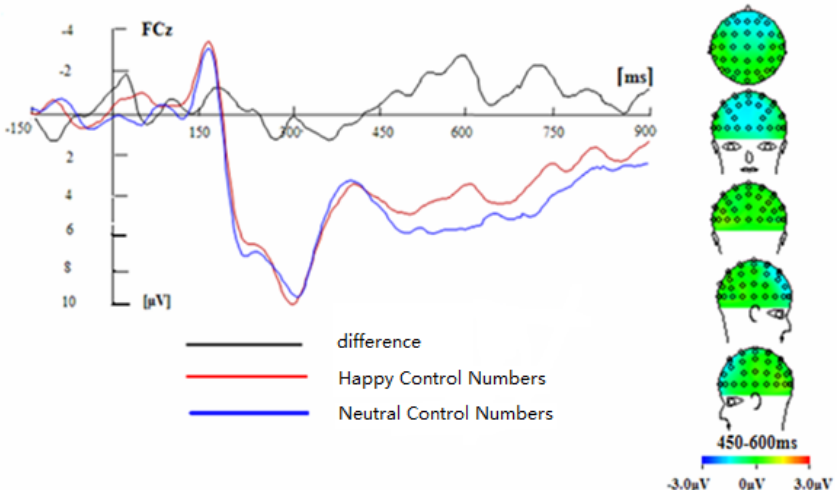


FIG.8. GRAND AVERAGE ERPS TO HAPPY CONTROL NUMBERS, NEUTRAL CONTROL NUMBERS, AND THE DIFFERENCE WAVE (HAPPY CONTROL NUMBERS–NEUTRAL CONTROL NUMBERS) AT FCZ IN THE TIME WINDOW OF 450-600 MS

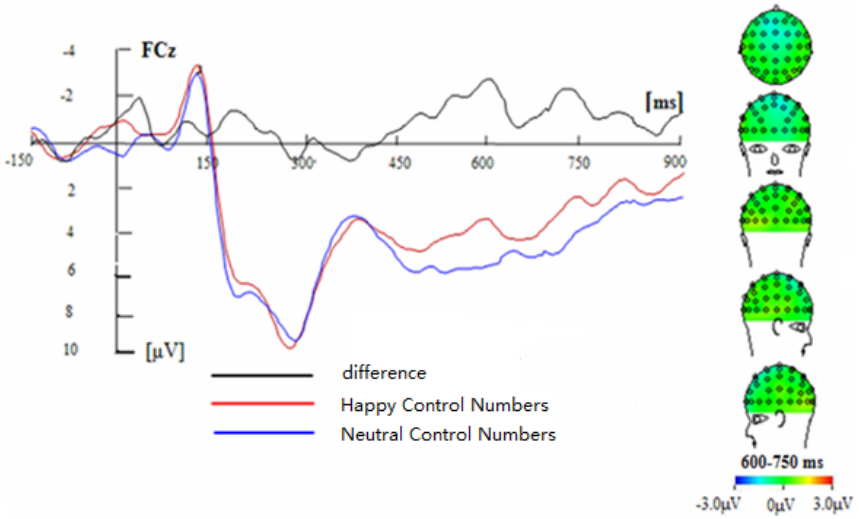


FIG.9. GRAND AVERAGE ERPS TO HAPPY CONTROL NUMBERS, NEUTRAL CONTROL NUMBERS, AND THE DIFFERENCE WAVE (HAPPY CONTROL NUMBERS-NEUTRAL CONTROL NUMBERS) AT FCZ IN THE TIME WINDOW OF 600-750 MS

A. Why do the new and neutral three-digit number stimuli (i.e. Happy Control Numbers) elicit P450-750 during post-conditioning phase?

Firstly, although from an evolutionary perspective, positive emotions are less salient or critical than negative emotions (Batty et al., 2003), they are very important for human emotional well-being (Fredrickson, 2005). Secondly, according to the broaden-and-build theory (Fredrickson, 1998, 2001), positive emotions can broaden the scope of attention. Furthermore, Wang et al. suggested that positive emotions bias attention toward novel stimuli based on the broaden-and-build theory (Fredrickson, 1998, 2001; Wang et al., 2008). Thus, a plausible interpretation for the P450-750 finding is that happiness elicited by happy facial expression stimuli during conditioning phase biased the participants' attention toward novel stimuli (i.e., Happy Control Numbers) (Wang et al., 2008), thereby affecting the timing of Happy Control Numbers (Murphy et al., 1993) during post-conditioning phase. Meaningfully, P450–750 was elicited by Happy Control Numbers, which were novel stimuli for participants; rather than Happy Generalized Numbers, which were similar stimuli for participants since Happy Generalized Numbers have the same clue number (i.e., 2) as Happy Conditioned Numbers (Watson et al., 1920).

Besides, we suspect that happy stimuli might bias participants' attention toward novel stimuli more easily than sad stimuli. Further studies employing a wide range of experimental tasks, designs, and recording methodologies (Carretié et al., 2005) would be informative in exploring the cognitive mechanisms and the neural basis of the biased attention toward novel stimuli elicited by positive emotional stimuli.

B. Was the sadness elicited by Sad Generalized Numbers implicit?

Firstly, the conditioning phase is emotion-unattended (i.e., the focus of attention was diverted away from the emotional facial expressions due to task instructions) (see page 7, implicit emotion task 1), indicating that sad and happy facial expression stimuli might be presented implicitly (Pessoa, 2005). In addition, the post-conditioning phase is emotion-unattended (see page10, implicit emotion task 2), indicating that sadness and happiness might be elicited implicitly.

Secondly, according to Watson et al. (Watson et al., 1920), we suggested that in our study the sadness of sad facial expression stimuli presented implicitly were conditioned to Sad Conditioned Numbers during conditioning phase and then generalized to Sad Generalized Numbers during post-conditioning phase. Therefore, a plausible interpretation for the P300-600 elicited by Sad Generalized Numbers in our study would be that the sadness of Sad Conditioned Numbers eventually generalized to Sad Generalized Numbers. Similar to facial EMG activity could be evidence indicating that a person is experiencing the emotion themselves (Bunce et al., 1999), we suggest that the P300-600 elicited by Sad Generalized Numbers might be psychophysiological evidence indicating that participants are experiencing the sadness themselves.

Thirdly, all participants verbally reported that they were emotionless during post-conditioning phase, which contained the time windows of 300-600 ms. It seems likely that even the most methodologically rigid experiments in cognitive science require introspective methodology at some level (Overgaard, 2006). Therefore, we argue that the participants' verbal reports indicating absence of emotional experiences during post-conditioning phase in our study were particularly important and useful; thus, these self-reported data could support the hypothesis that the emotions elicited by Sad Generalized Numbers were non-reporting emotions.

On the basis of these observations, it is conceivable that the sadness elicited by Sad Generalized Numbers is implicit, because (1) the sad facial expression stimuli might be presented implicitly during conditioning phase and the sadness might be induced implicitly during post-conditioning phase, and (2) these non-reporting emotions were experienced by participants psychophysiologically. Therefore, we argue that the generalization effect of conditioned sadness might be a novel approach to induce implicit sadness.

Overall, the present study is the first to use ERPs to investigate the electrophysiological correlates of implicit generalized conditioned sadness elicited by three-digit-number stimuli in a classical conditioning paradigm. The results showed that (1) the ERP component (P300-600) might be related to the implicit processing of generalized conditioned sadness, and (2) the ERP component (P450-750) might be related to the neural correlates of the biased attention toward novel stimuli elicited by positive emotional stimuli.

In addition, the ERP technology has some inevitable limitations. Thus, new studies should be performed using both ERPs and fMRI to investigate the spatiotemporal cortical activation patterns underlying the brain mechanism of generalized conditioned sadness processing, which could occur implicitly.

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