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Research article

Difficulties in implicit emotion regulation of the deaf college students: An ERP study

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ABSTRACT

Background: Deaf college students have been found to experience more difficulties in emotion regulation due to their hearing loss. However, few studies have used neurological measures to assess the characteristics of implicit emotion regulation among deaf college students.
Methods: 30 typical hearing college students and 27 deaf college students completed the implicit emotion regulation task while recording ERP data.
Results: The behavioral results indicated that deaf college students exhibited higher emotional experience intensity compared to typical hearing control. The ERP results showed that deaf college students had lower LPP amplitudes when using reappraisal and suppression strategies. Furthermore, the LPP of cognitive reappraisal was associated with an increase in depression scores among deaf students.
Conclusions: Deaf college students may have deficits in implicit emotion regulation, which can effectively predict depression.

1. Introduction

As we know, deaf college students who share traits of disabled person and college students, making them a significant portion of the special education population [1,2]. Previous results showed that the deaf college students have poorer mental health and are more prone to experience negative emotions during social interactions than typical hearing college students [1–7]. Moreover, researches utilizing the Difficulties in Emotion Regulation Scale (DERS) have demonstrated that hearing-impaired students experience more difficulties in emotion regulation [8,9], such as using more non-adaptive emotion regulation strategies [8,10–13], resulted in more impulsive behaviors. Studies using the Cognitive Emotion Regulation Questionnaire (CERQ) have shown that individuals with hearing impairments use emotion regulation strategies (e.g., expressive suppression and rumination) more frequently but utilize adaptive strategies like cognitive reappraisal difficultly [10,11,14].

Many studies have shown that emotion regulation strategies are not simply adaptive or maladaptive [15,16]. The adaptability of specific emotion regulation strategies is contingent upon the context [17]. When individuals confront stress, their coping mechanisms vary based on the emotion regulation strategies they used. Theorists have proposed a dynamic model comprising the person and the

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situation, which interact over time to facilitate adaptation [18]. Cognitive reappraisal and expression suppression stand out as the prevailing and efficacious strategies utilized by individuals during the onset of emotions [19,20]. Cognitive reappraisal as antecedent-focused emotion regulation, involves the early modification of emotions before emotional responses are activated [21,22]. Expression suppression as response-focused emotion regulation, which refers to the suppression of emotional expression behaviors that will occur or are occurring [23]. Due to their hearing impairment, individuals may face difficulty in conveying their emotions to others, consequently struggling to manage their emotions [24–26]. We have known that the regulation of responses to emotional stimuli is critical to mental health [27–29]. Enhancing the emotion regulation skills of deaf college students is crucial to enable them to seamlessly adjust to social situations and preserve their mental and physical well-being.

Most previous studies have focused on differences in explicit emotional regulation between deaf and typical hearing students behaviorally [30,31]. Contrarily, implicit emotion regulation does not involve conscious desire to change emotional responses [32], but rather can be triggered and shape behavior outside of conscious awareness [33]. It enhances coping with stressful events and requires less cognitive effort [34,35]. Typical hearing individuals can effectively regulated negative emotions through a word-matching task [36], which was also used in the present study to initiate implicit emotion regulation in subjects. Considering individuals with hearing impairments, they are struggling to reduce negative emotions and often use maladaptive emotion regulation strategies [9]. Despite numerous behavioral studies on deaf students, there are few researches utilizing electroencephalography (EEG) techniques to investigate the neural mechanisms underlying impaired implicit emotion regulation.

Event-related potentials (ERPs), as an objective measure of emotion regulation, use an electroencephalographic signal time-locked to specific events and have excellent temporal resolution [37]. Specifically, the amplitude of the late positive potential (LPP) is modulated by the intensity of emotion and is widely used in studies of emotion regulation, decreasing in adults and children after intentionally regulating emotions through strategies such as reappraisal and suppression [38–41]. It is a commonly used electrophysiological indicator in cognitive reappraisal EEG studies. Implicit reappraisal can successfully reduce the amplitude of late positive potentials [42]. Abnormal LPP has been observed in individuals with intrinsic psychopathology (e.g., depression and schizophrenia), indicating difficulties in emotion regulation [43–45]. However, few studies have used LPP to assess whether there are deficits in implicit emotion regulation in deaf college students. This study aims to investigate the characteristics of implicit emotion regulation in deaf college students by using ERP technology. We hypothesized that deaf college students experience emotions with stronger intensity and exhibit a lower LPP amplitude than typical hearing controls.

2. Methods and materials

2.1. Participants

Fifty-seven students (32 males and 25 females) from Chongqing Normal University were paid to participate in the experiment, with 30 typical hearing college students as the control group (age: 20.30 ± 1.97 years, 15 males and 15 females) and 27 deaf college students as the experimental group (age: 20.44 ± 1.60 years, 17 males and 10 females). All the deaf participants were college students enrolled in the Department of Special Education of the Normal University. They entered the university through a single examination and a single enrollment for undergraduate education, had access to the same educational resources as ordinary college students and were also eligible for master's degree programs. The deaf college students were sign language users, with an average hearing loss of 71 dB or more in both ears. All subjects were right-handed, of normal intelligence, normal or corrected-to-normal vision, and no history of neurological disorders or mental disease. Each participant signed the appropriate informed consent form prior to the experiment. After all experiments were completed, subjects were asked to complete the Chinese version of the Beck Depression Inventory-II (BDI–II–C) [46] and the Emotion Regulation Questionnaire (ERQ) [47]. The questionnaires were presented in written form and explained to the subjects. Table 1 provides detailed participant information. The research was approved by the local ethics committee (Institute of Psychology, Chongqing Normal University).

2.2. Instrumentation

2.2.1. Chinese version of the Beck Depression Inventory-II, BDI–II–C

The BDI–II–C scale is a 21-item scale with scores ranging from 0 to 3, designed to assess the degree of depressive symptoms within the past two weeks. The BDI–II–C scale is adaptive in the Chinese college student population [46]. The questionnaire was presented in written form and all subjects were able to understand the content of the questionnaire.

Table 1
Demographic and clinical characteristics of subjects ($N = 57$).

Measure	Typical Hearing Control Group	Deaf Student Group	Between-Groups p Value
Subjects	30	27	
Sex (male/female)	15/15	17/10	0.325
Age	20.30 (1.97)	20.44 (1.60)	0.764
ERQ			
Cognitive reappraisal	31.33 (5.74)	30.89 (5.00)	0.758
Expression suppression	7.57 (2.49)	10.74 (3.02)	<0.001

2.2.2. Emotion Regulation Questionnaire, ERQ

The ERQ scale was scored on a Likert 7-point scale with 10 questions (6 questions related to cognitive reappraisal and 4 questions related to expressive suppression), and the expressive suppression and cognitive reappraisal questions were summarized separately, with higher scores indicating higher use of the strategy. The reliability and validity of the Chinese version of the Emotional Regulation Questionnaire met the psychometric requirements [47].

2.3. Stimuli

2.3.1. Faces

Forty sad images were selected from the Chinese Facial Affective Picture System (CFAPS) [48], with half of the images for each gender. Forty subjects were selected to rate the arousal of sad pictures, and an independent samples *t*-test found no significant difference in the arousal of the selected sad pictures by gender ($t = 1.787$, $p = 0.97$). The participants were seated in a quiet room with their eyes 70 cm from the screen and a horizontal and vertical viewing angle of less than 5°. All images were presented at the same brightness and contrast on a black background (central presentation).

2.3.2. Priming words

To prime implicit emotion regulation, the word matching task consists of 60 words, which frequently encountered in everyday life either advise people to remain calm in emergency situations or encourage them to hide their inner emotions [49]. It can be divided into three categories according to their meaning, namely 20 each of cognitive reappraisal, expression suppression and neutral words. The cognitive reappraisal and expression suppression words, which belong to the category of emotion regulation words, have been shown to be effective in reducing negative emotional experiences [49–51]. All words were selected from Chinese Emotion Regulation Word System (CERWS) [49]. One-way ANOVAs revealed no significant differences in validity ($F = 2.254$, $p = 0.104$), arousal ($F = 1.897$, $p = 0.162$), and familiarity ($F = 1.941$, $p = 0.156$) between cognitive reappraisal words, expressive suppression words and neutral words.

2.4. Experimental design and procedure

The procedure was programmed and performed using E-prime 3.0. The design of the task was based on previous research [36, 52–54]. The experimental task was divided into 3 conditions of 6 blocks, each consisting of 2 successive blocks, according to the type of words in the word matching task. As shown in Fig. 1, each block required participants to complete 20 trials of word matching task, followed by 30 trials of view negative images, and each block ended with one trial of the emotion assessment task (EA task). In the

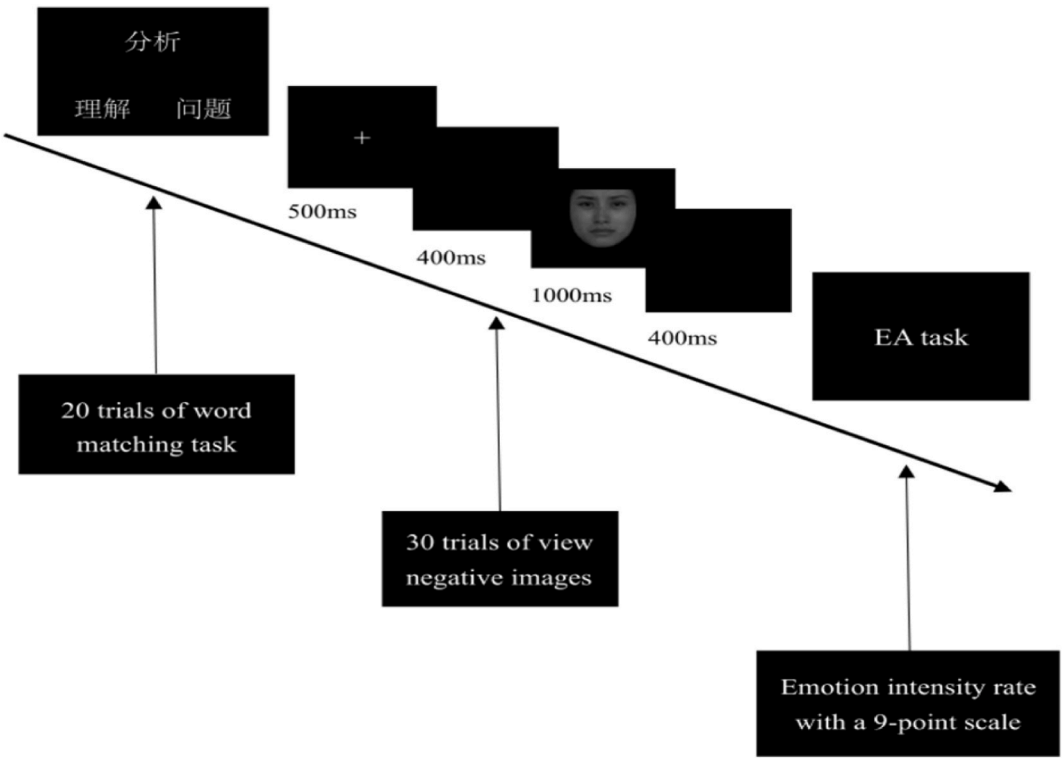

Fig. 1. The sequence of the task in one single block.

word matching task, participants were asked to choose from two words at the bottom of the screen (F for the left alternative and J for the right) to match the meaning of a third word in the center of the screen. In the emotion regulation condition, two words in each word matching task were emotion regulation words and the other word was a neutral word; whereas in the neutral condition, all three words were neutral words. When viewing the negative images, a fixation cross was presented at the center of the screen for 500 ms, followed by a 400 ms blank screen, then a facial picture was presented for 1000 ms. After the picture disappeared, a 400 ms blank screen was presented between trials. When all the images were presented, participants were asked to rate the intensity of the emotions they experienced in the moment (EA task) on a 9-point scale. After completing all these tasks, participants were asked to report whether they had guessed the relationship between the word matching task and the viewing of the negative images.

A pseudo-randomized design was used in this study, and the neutral block was placed before the emotion regulation block in order to avoid the effect of the regulation condition on the neutral condition. The order between the cognitive reappraisal block and the expression suppression block was balanced.

2.4.1. EEG recording

EEG was continuously recorded using a 64-channel Ag–AgCl electrode cap (Brain Products) based on the 10–20 International System. Bilateral mastoids were used as reference electrodes (bilateral mastoids were averaged for reference) and electrodes were placed laterally in both eyes to record horizontal electro-oculography and above and below the left eye to record vertical electro-oculography. Scalp impedance for each electrode was kept below 5 KΩ. EEG data preprocessing was conducted using MATLAB (version9.3.0.713579 [R2017b]; The MathWorks, Inc.) script set developed by the authors, containing both original and EEGLAB functions [55], while ERP analysis was performed in the Psychophysiology Toolbox [56]. EEG signal was filtered using a range of 0.05–100 Hz and sampled using the rate of 500 Hz. The data was processed offline after completion of continuous recording of the EEG. The offline analysis period was 1200 ms, including 200 ms before the presentation of the feedback stimulus (as a baseline) and 1000 ms after the presentation for analysis. Segments were manually inspected to ensure exclusion of trials with artifact.

2.4.2. Data analysis

The emotional experience intensity rating and ERP data were analyzed separately using a 2 (group: deaf student group/typical hearing control group) × 3 (condition: neutral/cognitive reappraisal/expression suppression) repeated-measures ANOVA [21,28]. According to the literature [37,57,58] and visual inspection of the topographical distribution of grand averaged ERP activity, LPP was measured as the average activity of CPz, CP1, CP2 and the average amplitudes calculation window was 340–540 ms.

The Greenhouse-Geisser correction was used to compensate for sphericity violations. Least significant difference (LSD) was applied for post hoc testing of main effects. Partial eta-squared (η_p^2) was reported as indicator of the effect size in ANOVA tests. All these statistical analyses were conducted with SPSS 23.0 software.

3. Results

3.1. Behavioral data

Emotional experience intensity rating scores were analyzed using a 2 (group: deaf student group/typical hearing control group) × 3 (condition: neutral/cognitive reappraisal/expression suppression) repeated-measures ANOVA which revealed a marginally significant main effect of group ($F_{(1, 55)} = 3.823$, $p = 0.056$, $\eta_p^2 = 0.065$), whereby the deaf student group ($M = 4.790$, $SD = 0.334$) was associated with a larger emotional intensity score than the control group ($M = 3.889$, $SD = 0.317$) (Table 2).

3.2. ERP results

For LPP amplitudes, we conducted a 2 (group: deaf student group/typical hearing control group) × 3 (condition: neutral/cognitive reappraisal/expression suppression) repeated measures ANOVA. The result indicated a significant main effect of group ($F_{(1, 55)} = 7.006$, $p = 0.011$, $\eta_p^2 = 0.113$) (Fig. 2, Fig. 3). Specifically, the deaf student group ($M = 2.681$, $SD = 0.344$) elicited lower LPP than the typical hearing control group ($M = 3.935$, $SD = 0.326$). However, the main effect of condition was not significant ($F_{(2, 110)} = 2.057$, $p = 0.138$, $\eta_p^2 = 0.071$) (Table 2).

To our surprise, we found a correlation between depression scores and LPP amplitudes among the deaf students. Pearson

Table 2
Emotional experience intensity and LPP amplitudes during the task.

Group	neutral	cognitive reappraisal	expression suppression
Emotional experience intensity, Mean (SE)			
Typical Hearing Control Group	4.52 (1.95)	3.52 (1.83)	3.63 (1.95)
Deaf Student Group	5.02 (2.04)	4.41 (1.69)	4.94 (2.13)
LPP amplitudes, Mean (SE)			
Typical Hearing Control Group	4.38 (2.71)	3.72 (1.78)	3.71 (2.26)
Deaf Student Group	2.90 (1.86)	2.73 (1.98)	2.41 (1.76)

A significant main effect of condition ($F_{(2, 110)} = 6.987$, $p = 0.002$, $\eta_p^2 = 0.206$) was found, and the cognitive reappraisal ($M = 3.962$, $SD = 0.234$) and expression suppression ($M = 4.289$, $SD = 0.270$) words were significantly reduced emotional intensity than neutral words ($M = 4.768$, $SD = 0.264$).

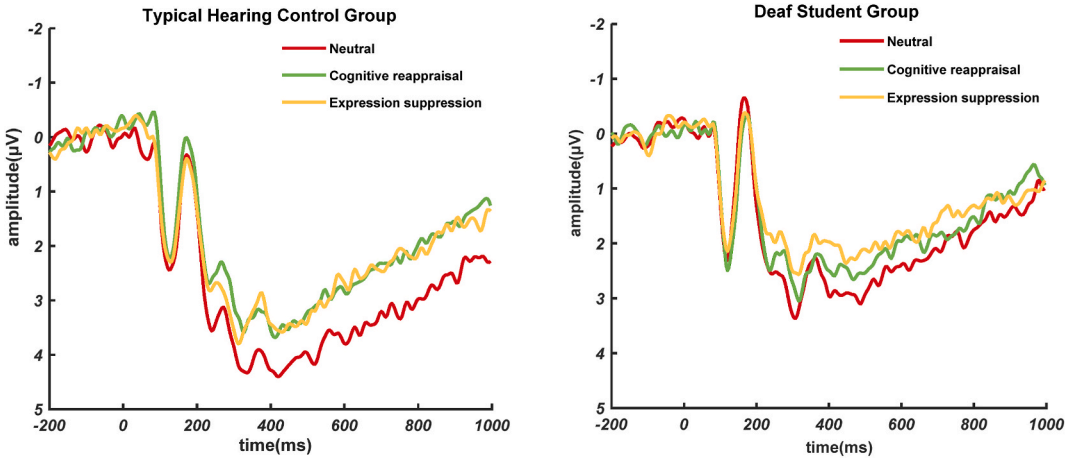

Fig. 2. Grand average event-related potential at the CPz site during three conditions for the deaf student group and the typical hearing control group.

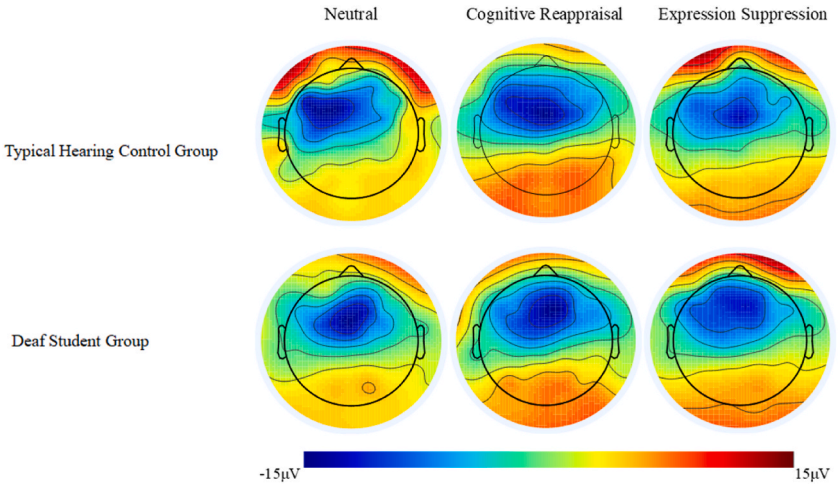

Fig. 3. Scalp topography of LPP across three conditions at 340–540 ms.

correlation coefficients showed that decreases in depression scores were significantly correlated with the enlargement of LPP amplitudes for cognitive reappraisal words ($r_{(27)} = -0.389$, $p = 0.045$).

4. Discussion

We used ERP to explore the characteristics of implicit emotion regulation in deaf college students. The results indicated that the deaf student group exhibited higher emotional experience intensity rating scores and lower LPP amplitudes when reappraisal and suppression emotional stimuli were compared to the typical hearing control group. Furthermore, the LPP of cognitive reappraisal was associated with an increase in depression scores among deaf college students.

As we know, emotional intensity scores indicated that implicit emotion regulation is an effective method of regulation [52,53]. The behavioral results demonstrated that all participants experienced lower subjective emotion under words related to emotional regulation than neutral words, which is consistent with previous studies [35,59]. However, our findings further found that deaf college students had higher emotional experience intensity than typical hearing college students when engaging in cognitive reappraisal and expression suppression. Previous studies have demonstrated hearing-impaired adolescents frequently encounter difficulties in cognitive emotion regulation [11,30]. That is to say, the results provide more evidence for the deaf college students behaved more impulsively and lower self-control when experiencing negative emotions than typical hearing college students [8].

The ERP results indicated that deaf college students had significantly lower LPP amplitudes during reappraisal and suppression emotional stimuli than typical hearing college students. Many studies focusing on drug abuse and depression have indicated that individuals with increased symptoms of depression or diagnosed depression exhibit an abnormal LPP, which is unresponsive to

emotional stimuli [44,57,60–64]. In addition, adolescents at risk of depression with changes in LPP were observed prior to the onset of symptoms [65,66]. Even deaf children showed diminished activation in the LPP [67]. In a word, LPP reflects the intensity of motivation, rather than its direction. However, emotional valence is associated with the direction of motivation, and negative emotion is related to the avoidance of motivation [68]. Previous results showed that the stronger the avoidance motivation, the greater the LPP amplitudes induced by the negative stimulus [57,69,70]. This suggests that the deaf college students exhibited a reduced motivation to avoid negative stimuli. Consequently, they were unable to avoid negative stimuli and events in a timely manner, which in turn led to an increased experience of negative emotions in their lives.

Additionally, we discovered that LPP amplitudes induced by cognitive reappraisal were negatively associated with depression scores in deaf college students. Previous studies have shown that LPP are negatively associated with depression when viewing emotional images [61,62,64]. The cognitive reappraisal strategy was associated with reduced depression by changing individuals' perceptions of negative stimuli [71,72]. Our results suggested that among deaf college students, the higher the level of depression, the more difficult to regulate negative emotions when using implicit cognitive reappraisal strategies.

Furthermore, both emotional experience intensity and LPP found that deaf college students were less efficient in using cognitive reappraisal to regulate emotions than typical hearing college students. Therefore, deaf college students may not effectively use cognitive reappraisal to regulate their negative emotions. Future research could use cognitive behavioral therapy using reappraisal as a core technique to explore whether it could improve the ability of deaf college students to regulate their emotions.

Even we have revealed the characteristics of implicit emotion regulation in deaf college students by using ERP, there are still have the following limitations. First, the sample size of this study was small and the study group was single only deaf college students, so the findings may not be generalizable to other deaf groups. Second, the study results appear to be marginally significant, which may be due to the insufficient sample size. Future research could investigate the causes of developmental delays in deaf individuals by increasing the number of subjects and subject groups, as well as considering variables that may be associated with difficulties in emotion regulation. These variables could include the degree of hearing loss, the type of previous education, language and cognitive experiences, etc. Finally, the ERP technique used in this study has high temporal resolution but poor spatial resolution, which does not allow precise localization of brain area activation. Thus, integration of techniques can be taken into consideration in future research. For example, this study mainly explored the neurophysiological mechanisms of emotion regulation in deaf students through the ERP technique. Future studies can incorporate additional techniques, such as fMRI, fNIRS, and transcranial magnetism, to conduct a more comprehensive investigation.

5. Conclusion

In conclusion, the study suggested that deaf college students may have deficits in implicit emotion regulation. The results demonstrated that deaf college students exhibited heightened emotional experience intensity and lower LPP amplitudes when reappraising and suppressing emotional stimuli compared to typical hearing college students. Moreover, the decrease in cognitive reappraisal LPP was associated an increase in depression scores among deaf college students.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the Declaration of Helsinki and approved by the ethical committee of College of Educational Sciences, Chongqing Normal University (CNU-PSY-202205-020).

Informed consent

Informed consent was obtained from all individual participants included in the study. Informed consent was obtained from the individuals for the publication of any potentially identifiable images or data included in this article. All methods were carried out in accordance with relevant guidelines and regulations.

Data availability statement

The data associated with our study has not been deposited into a publicly available repository. Data will be made available on request.

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CRediT authorship contribution statement

Xue Du: Writing – review & editing, Funding acquisition, Conceptualization. **Ting Huang:** Writing – review & editing, Visualization, Validation. **Xingru Wang:** Writing – original draft, Investigation. **Shiqiong Wu:** Investigation. **Xiaoyi Chen:** Writing – review & editing. **Jun Jiang:** Formal analysis. **Dongtao Wei:** Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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