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Parental presence with encouragement alters feedback processing in preschoolers: An ERP study

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Abstract

External feedback plays an important role in adapting to the environment; however, feedback processing in preschoolers has not been fully understood. The present event-related brain potential (ERP) study sought to understand the influence of parental presence with encouragement on feedback processing by focusing on reward positivity (RewP: mean amplitude between 200-350 ms). Five-year-old children (*N* = 21) completed an animal search task both alone (the alone condition) and with a parent who offered words of encouragement (the with a parent condition). ERPs were recorded while they received negative and positive feedback. We found a larger RewP amplitude in response to positive feedback in the with a parent condition relative to in the alone condition. In addition, differences in RewP between positive and negative feedback were only observed in the with a parent condition. These findings suggest that everyday parental encouragement has the potential to promote differential positive and negative feedback processing possibly by enhancing the reward value of positive feedback.

Keywords: feedback processing, RewP, parental encouragement

Introduction

External feedback provides essential information about the consequences of acts that help optimize goal-directed behaviors and learning. Adult electrophysiological research has suggested the presence of reward positivity (RewP)—event-related potential (ERP) component peaking approximately 250-350 ms after feedback onset at the middle front-central site—when participants received favorable feedback (e.g., correct feedback, monetary gain) (e.g., Belden et al., 2016; Proudfit, 2015). The source of RewP is considered to be the ventral stratum and medial frontal cortex (MPFC) (e.g., Carlson, Foti, Mujica-Parodi, Harmon-Jones, & Hajcak, 2011; Foti, Weinberg, Dien, & Hajcak, 2011). Similarly, a negativity in response to unfavorable feedback (e.g., error feedback, monetary loss)—feedback-related negativity (FRN) (e.g., Miltner, Braun, & Coles, 1997; Ullsperger, Fischer, Nigbur, & Endrass, 2014)—also seems to have an important role in feedback processing. The source of FRN is considered to be the anterior cingulate cortex (ACC) and MPFC (e.g., Miltner et al., 1997; Segalowitz et al., 2012), which is the center of performance monitoring, learning, and affective processing (e.g., Botvinick, Cohen, & Carter, 2004; Etkin, Egner, & Kalisch, 2011; Ferdinand & Kray, 2014). Based on the recent findings indicating that variations in the ERP component between positive and negative feedback types might be driven by neural responses to rewards (e.g., Carlson et al., 2011; Foti et al., 2011; Proudfit, 2015), we formulated the hypothesis of the current study by using the term RewP.

Evidence of feedback processing in early childhood, however, has been mixed. A previous study revealed that 2.5-year-old toddlers exhibited FRN in a gambling task using animal images (Meyer, Bekkering, Janssen, de Bruijn, & Hunnius, 2014); however, 5-year-old preschoolers did not show FRN during a prize guessing task (Mai et al., 2011). Another study showed that 8- to 10-year-old children exhibit mid-frontal negativity in response to unfair offers from similar aged children during an ultimatum game (Rêgo et al., 2016). Finally, healthy preschoolers (4- to 7-year-olds) showed increased RewP in response to positive feedback as compared to depressed counterparts (Belden et al., 2016). These findings indicate that feedback processing in early childhood might reflect an immature state of development, especially for the MPFC or the ACC which are important for external feedback processing and the executive function (e.g., Kelly et al., 2009; Mai et al., 2011). However, it is also possible that development of preschoolers' feedback processing is underestimated because of situational or motivational factors. Ferdinand and Kray (2014) argued that factors increasing the motivation to stick to a task should be emphasized to further clarify feedback processing in children. The present study sought to elucidate feedback processing in 5-year-old preschoolers by focusing on one such factor, namely, parental presence with encouragement during the task.

Preschoolers and toddlers sometimes conduct tasks with their parents or an experimenter that offer words of encouragement. The presence of parents and words of encouragement are considered to be important for children to maintain the involvement with a task and motivation (e.g., Meyer et al., 2014; Picton et al., 2000). However, parental presence and encouragement may alter feedback processing. For example, previous adult and adolescent studies have revealed that the presence of an audience influences feedback processing (e.g., Kessler, Hewig, Weichold, Silbereisen, & Miltner, 2017; Segalowitz et al., 2012; Tian et al., 2015). One study demonstrated that positive feedback elicited a larger positivity in the audience condition than the alone condition (Tian et al., 2015). Moreover, a larger FRN difference amplitude (i.e., amplitude evoked by negative feedback minus those by positive feedback) was observed in the audience condition in comparison to the alone condition. We therefore predicted that (a) RewP in response to positive feedback would be larger when conducting a task with a parent who encourages their child as compared to when conducting the task alone, and that (b) differences between positive and negative feedback would be larger when conducting the task with a parent who encourages the child as compared to when conducting the task alone.

In addition to the influence of the presence of a parent with encouragement, task characteristics may affect feedback processing (Ferdinand and Kray, 2014). More specifically, age-appropriate tasks seem important for investigating feedback processing in children (e.g., Mayer et al., 2014; Grabell, Olson, Tardif, Thompson, & Gehring, 2017). Previous studies revealed that task involvement and interest for a task is associated with enhanced feedback processing (e.g., Li, Han, Lei, Holroyd, & Li, 2011; Yeung, Holroyd, & Cohen, 2005). We therefore used animal images similar to a previous study (Meyer et al., 2014) and conducted a task in which feedback is not determined randomly, but is instead determined by preschoolers' own performance in order to help enhance task involvement and interest.

Methods

Participants

Thirty preschoolers participated in the experiment with their parent. Within this group, 21 children conducted a task under both conditions (11 girls, *M* = 63.6 months, *SD* = 2.3) and 8 children conducted a task only with their parent, and one child could only conduct the task alone. There was no significant age difference between children who could perform the task in both conditions and those who could perform it only with their parent ($t(27) = .91$, $p = .37$). An additional eight children were tested but excluded from analyses because of excessive artifacts (less than 5 artifact-free trials, n = 2; Grabell et al., 2017), insufficient number of trials (n = 3), and refusing to wear an EEG cap (n = 3). Parents reported that their child was typically developing, and had the necessary cognitive skills and adequate vision to comprehend the current task.

Each parent gave written consent after both parent and child were informed about the purpose and method of the study. Participants received ¥ 2,000 for their participation. The Human Research Ethics Committee of the University of Tokyo approved the study protocol.

Procedure

Preschoolers performed a “find an animal task” (Figure 1A), which is a child-friendly task that we have developed. In this task, they were required to search for a target animal by pressing a button (left or right) using a response pad (Cedrus, RB-844). Participants were verbally instructed that the aim of this game was to find as many animals as possible and, because animals are quick at running away, they have to find the target animal as quickly as possible. In addition, they were told that sometimes a target animal is not presented on the test trial (NO-GO trial) and to not press any button at that time. NO-GO trials were included to test whether response inhibition would change between conditions.

We used animal images that are typically familiar with preschoolers (e.g., pig, dog, and cat, https://www.irasutoya.com/2014/08/blog-post_69.html). The task was programmed using Inquisit 4 software. Each trial began with a target animal image that was presented on the upper side of the screen (1500 ms). Next, ten animals were presented on the bottom side of screen, half of which were presented on the left side and half of which were presented on the right side on the screen (test trial). The proportions of target animals presented on the right or left side of the screen were comparable (i.e., 0.5:0.5). The duration of the test trial differed across trials and was determined based on the participant's ability to maintain a positive and negative feedback ratio that was approximately equal (i.e., 50 %) to reduce the influence of feedback frequencies on feedback processing. If the participant could find a target animal in the previous trial within the time limit, the trial duration was shortened by 200 ms from the mean duration of prior trials. Otherwise, trial duration was lengthened by 200 ms. Following the presentation of a blank screen (1000-1500 ms), feedback was presented. The participant received positive feedback (○) if they correctly responded within time limits; otherwise, they received negative feedback (×). Feedback was presented approximately 5 inches on the screen.

Preschoolers completed the task in a single visit to the lab. Participants completed the task alone (the alone condition) and in the presence of a parent who sat beside the participant (the with a parent condition). The order of two conditions was counterbalanced across participants. During the with a parent condition, the parent was instructed to verbally encourage but not interfere with task play. Preschoolers could play 120 trials including 20 NO-GO trials in each condition, separated into two blocks (e.g., each block has 60 trials including 10 NO-GO trials).

ERP recording and processing

An electroencephalogram (EEG) was used to record data with a 65-channel Electrical geodesics system. The signal was recorded with a bandpass filter of 0.1-100 Hz referenced to vertex at a sampling rate of 1000 Hz. Data were processed using Brain Vision Analyzer 2 (Brain Products GmbH) software. A filter of 0.5-30 Hz was applied to the ERP and re-referenced to averaged mastoids. Trials that contained motor and ocular artifacts were excluded from averaging. ERP waveforms were obtained by averaging a 600-ms period 100 ms before and 500 ms after the onset of a feedback stimulus. A 2 (condition: with a parent vs. alone) × 2 (feedback type: positive vs. negative) ANOVA only indicated the main effect of feedback ($F(1,20) = 13.98$, $p = .001$, $\eta_p^2 = .41$) such that positive feedback had more artifact-free trials (with a parent: Range = 9 – 39 trials, *M* = 23.9, *SD* = 10.0, alone: Range = 5 – 48 trials, *M* = 24.9, *SD* = 12.3) than negative feedback (with a parent: Range = 7 – 32 trials, *M* = 17.7, *SD* = 7.2, alone: Range = 5 – 47 trials, *M* = 21.5, *SD* = 13.4). Based on visual inspection in previous studies showing that the difference between positive and negative feedback started at 200 ms (Belden et al., 2016; Meyer et al., 2014; Rêgo et al., 2016) and ground-average waveform from the current study, the amplitude of RewP was measured around FCz (channel numbers 4, 7, and 54) as having a mean amplitude of 200 to 350 ms.

Data analysis

To analyze behavioral outcomes, a paired sample t-test (condition: with a parent vs. alone) was conducted. For RewP, we conducted a 2 (condition: with a parent vs. alone) × 2 (feedback type: positive vs. negative) ANOVA.

Results

Behavioral outcomes

Table 1 shows descriptive variables of behavioral outcomes. As shown in Table 1, negative feedback rate, incorrect response rate, correct response time, and NO-GO response rate did not differ significantly between conditions.

RewP

Figures 1B and C indicate the results of the grand-average waveform and topography map of each condition. An ANOVA conducted on RewP indicated a significant main effect of feedback ($F(1,20) = 13.58$, $p = .001$, $\eta_p^2 = .40$): Positive feedback elicited more positive amplitude than did negative feedback. We also found a significant interaction between feedback and condition ($F(1,20) = 18.09$, $p < .001$, $\eta_p^2 = .48$) such that positive feedback elicited more positive amplitude in the with a parent condition relative to the alone condition ($t(20) = 3.40$, $p = .003$, $d = .50$). There was no significant difference between conditions in response to negative feedback ($t(20) = 1.92$, $p = .07$, $d = .46$). In addition, the difference between positive feedback and negative feedback was significant for the with a parent condition ($t(20) = 5.50$, $p < .001$, $d = .92$): Positive feedback elicited more positive amplitude as compared to negative feedback. There was no such difference for the alone condition

($t(20) = .28$, $p = .78$, $d = .04$). The main effect of condition was not significant ($F(1,20) = .06$, $p = .80$, $\eta_p^2 = .003$).

Discussion

The purpose of the present study was to investigate feedback processing in preschoolers by focusing on the presence of a parent who encourages their child. We found (a) RewP in response to positive feedback was larger when conducting a task with a parent who encouraged the child as compared to when conducting the task alone, and (b) differences in RewP between positive and negative feedback was only observed when conducting the task with a parent who encouraged the child.

These findings extend previous studies by showing that feedback processing is modulated by the presence of a parent with encouragement. These results are in line with adult research revealing an audience effect on feedback processing (e.g., Kessler et al., 2017; Tian et al., 2015), as well as studies showing the presence of FRN and RewP in children (e.g., Belden et al., 2016; Meyer et al., 2014; Rêgo et al., 2016). Our findings imply that feedback processing in preschoolers is susceptible to social context. One prior study has suggested that feedback processing in early childhood might reflect an immature state of development, making it potentially difficult to differentiate between good and bad feedback (e.g., Mai et al., 2011). Our findings suggest that encouragement by parents could help promote the differentiation of positive and negative feedback processing in preschoolers.

More specifically, encouragement by parents helped to promote the differentiation by altering positive feedback processing, but not by altering negative feedback processing. These findings are in line with a previous study that indicated the importance of reward processing rather than loss processing in preschoolers (Belden et al., 2016). Our findings suggest that parental encouragement in preschoolers have the potential to increase the reward value of positive feedback. Also, given that blunted RewP is one underlying mechanism of depression in children and adults (e.g., Belden et al., 2016; Proudfit, 2015), parental encouragement might have the potential to enhance, or protect from decreasing reward processing.

This study demonstrated that parental encouragement helps to promote the differentiation of positive and negative feedback processing by altering positive feedback processing, and improves our understanding of feedback processing in preschoolers. The study had a relatively small sample size and was conducted in Japan, which is known to have an interdependent culture (Markus & Kitayama, 1991). Therefore, future studies would benefit from investigating cultural commonalities and specificities of feedback processing using a larger sample size.

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Table

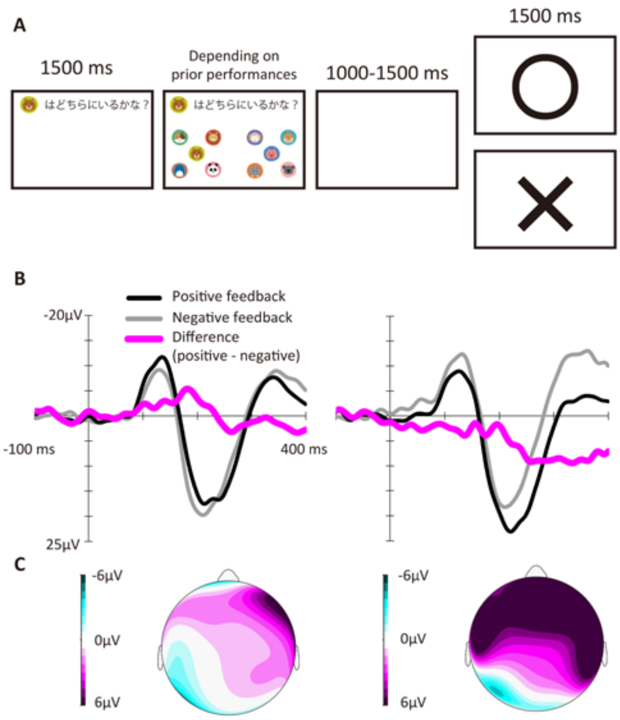
Table 1. Descriptive statistics of behavioral outcomes and RewP

	With parent	Alone	Statistics
Negative feedback rate (%)	50.8±3.0	51.5±2.3	$t(20) = .73$, $p = .48$
Incorrect response rate (%)	3.6±2.9	3.3±3.3	$t(20) = .25$, $p = .81$
Correct reaction time (ms)	1232.9±279.2	1296.9±337.6	$t(20) = .98$, $p = .34$
NO-GO response rate (%)	15.9±17.3	17.5±19.9	$t(20) = .35$, $p = .73$
RewP (Positive feedback: μV)	11.1±10.7	6.0±9.8	-
RewP (Negative feedback: μV)	2.1±8.9	6.5±10.2	-

Figure caption

Task and results of current study. (A) A schematic diagram of the “find an animal task.” (B) Grand mean ERP waveforms at FCz (mean amplitude at channel 4, 7, 54) elicited by positive feedback (black line), negative feedback (gray line), and difference wave (positive feedback – negative feedback: red line) for alone (left) and with a parent conditions (right). (C) Topographical maps of the difference wave (positive feedback – negative feedback) around 200-350ms for alone (left) and with a parent conditions (right).

Figure


A
1500 ms
Depending on
prior performances
1000-1500 ms
1500 ms
はどちらにいるかな？
はどちらにいるかな？
B
Positive feedback
Negative feedback
Difference
(positive - negative)
-20μV
-100 ms
400 ms
25μV
C
-6μV
0μV
6μV
-6μV
0μV
6μV