Developmental Cognitive Neuroscience 24 (2017) 107–117

Contents lists available at ScienceDirect

Developmental Cognitive Neuroscience

journal homepage: http://www.elsevier.com/locate/dcn

The neural and behavioral correlates of social evaluation in childhood

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ARTICLE INFO

Article history:
Received 2 August 2016
Received in revised form 16 February 2017
Accepted 17 February 2017
Available online 27 February 2017

Keywords:
Social feedback
Social rejection
Aggression
Childhood
Amygdala
Meta-analysis

ABSTRACT

Being accepted or rejected by peers is highly salient for developing social relations in childhood. We investigated the behavioral and neural correlates of social feedback and subsequent aggression in 7–10-year-old children, using the Social Network Aggression Task (SNAT). Participants viewed pictures of peers that gave positive, neutral or negative feedback to the participant's profile. Next, participants could blast a loud noise towards the peer, as an index of aggression. We included three groups ($N = 19$, $N = 28$ and $N = 27$) and combined the results meta-analytically. Negative social feedback resulted in the most behavioral aggression, with large combined effect-sizes. Whole brain condition effects for each separate sample failed to show robust effects, possibly due to the small samples. Exploratory analyses over the combined test and replication samples confirmed heightened activation in the medial prefrontal cortex (mPFC) after negative social feedback. Moreover, meta-analyses of activity in predefined regions of interest showed that negative social feedback resulted in more neural activation in the amygdala, anterior insula and the mPFC/anterior cingulate cortex. Together, the results show that social motivation is already highly salient in middle childhood, and indicate that the SNAT is a valid paradigm for assessing the neural and behavioral correlates of social evaluation in children.

1. Introduction

Social acceptance is of key importance in life. Receiving positive social feedback increases our self-esteem and gives us a sense of belonging (Thomaes et al., 2011). Receiving negative social feedback, in contrast, can induce feelings of depression, and rejected people often react with withdrawal (Nolan et al., 2003). Social rejection can, however, also trigger feelings of anger and frustration, and can lead to reactive aggressive behavior (Dodge et al., 2003; Nesdale and Lambert, 2007; Chester et al., 2014; Riva et al., 2015; Achterberg et al., 2016). Most developmental studies have focused on the withdrawal reaction after social rejection, while relatively few have examined reactive aggression. The few studies that examined rejection-related aggression showed that early peer rejection was associated with an increase in aggression in children aged 6–8 (Dodge et al., 2003; Lansford et al., 2010). Several prior studies have also shown that rejection can lead to immediate aggression (Chester et al., 2014; Riva et al., 2015; Achterberg et al., 2016). These immediate effects may be associated with emotional responses to rejection and a lack of impulse control. Although several studies have focused on neural processes involved in negative versus positive social feedback processing, the neural processes involved in dealing with negative or positive social feedback versus a neutral baseline in middle childhood are currently unknown.

Experimental research in adults has examined social evaluation and aggression using a peer acceptance and rejection task. Initially developed as a social feedback task (Somerville et al., 2006), a recent adaptation allowed participants to deliver noise blasts to peers who had rejected them based on a personal profile (Achterberg et al., 2016), testing the potential expression of reactive aggression. Negative social feedback signaling rejection was associated with louder noise blasts and increased activity in bilateral anterior insula and medial prefrontal cortex (mPFC)/anterior cingulate cortex (ACC) relative to neutral feedback (Achterberg et al., 2016). This latter region is suggested to play an important role in evaluating others' behaviors and in estimating others' level of motivation (Flagan and Beer, 2013; Apps et al., 2016). Interestingly, these regions were also more active after positive feedback (compared to neutral feedback), suggesting that both negative and positive feedback leads to social evaluative processes in adults. Other studies also reported the involvement of subcortical regions in processing social feedback.

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http://dx.doi.org/10.1016/j.dcn.2017.02.007
1878-9293/

Positive social feedback was found to result in greater activity in striatal regions (Gunther Moor et al., 2010; Achterberg et al., 2016), which possibly reflects the rewarding value of this type of feedback (Guyer et al., 2014). Furthermore, peer interactions have been associated with increased amygdala activity, indicating their affective salience (Guyer et al., 2008; Masten et al., 2009; Silk et al., 2014).

Several studies examined the neural correlates of social evaluation in children and adolescents. These studies reported increased neural activity to positive relative to negative feedback in older adolescents and adults (16–25) as indicated by increased activity in the ventral mPFC, the subcallosal cortex, and the ACC (Gunther Moor et al., 2010). Another study found increased pupil dilation in response to social rejection (compared to acceptance) in children aged 9–17 (Silk et al., 2012a). Pupil dilation is an index of increased activity in cognitive and affective processing regions of the brain, such as the ACC and amygdala (Silk et al., 2012a), and the pupil becomes more dilated in response to stimuli with a greater emotional intensity (Siegle et al., 2003). Interestingly, the pupil dilation effect was larger for older participants, indicating that adolescents reacted more strongly to rejection than children. The current study examined the neural correlates of social evaluation in middle childhood, prior to adolescence, because the first long-lasting friendships gradually emerge around this time (Berndt, 2004). Furthermore, we tested whether peer rejection in children results in behavioral aggression, in a similar way as was previously observed in adults (Chester et al., 2014; Riva et al., 2015; Achterberg et al., 2016).

Thus, our aim was to investigate 7–10-year-old children's responses to social evaluation in terms of neural activity and reactive behavioral aggression. For this purpose, we used the Social Network Aggression Task (SNAT), that elicited robust neural and behavioral responses in adults (Achterberg et al., 2016), but has not yet been used with children. During the SNAT, participants viewed pictures of peers who gave positive, neutral or negative feedback to the participant's profile. Next, participants could deliver an imagined noise blast towards the peer, as an index of (imagined) aggression or frustration. Since recent studies have reported concerns about the replicability of psychological science (for example see Open Science (2015)), we used three samples to validate the paradigm: a pilot sample, a test sample, and a replication sample. Moreover, findings that may show no evidence of significance when analyzed individually might provide stronger evidence when collapsed across experiments, as was recently shown (Scheibehenne et al., 2016). Therefore we also include a meta-analytic combination of the results across the three samples.

On the behavioral level we expected that the pattern of aggression after positive, neutral, and negative feedback would be similar across the pilot, test and replication samples, with negative feedback resulting in the highest levels of aggressive behavior. On the neural level we examined both the general contrast of social evaluation (all feedback conditions vs. baseline; see Supplementary materials) and the condition-specific contrasts. To further investigate condition effects, that is the effect of negative *vs.* neutral *vs.* positive feedback, we used regions of interest (ROI) analyses. The individual ROI analyses were meta-analytically combined in order to test for robust condition effects across our samples. Based on studies in adults, the predictions were that negative social feedback would be associated with increased activity in the amygdala (Masten et al., 2009), bilateral insula, and mPFC/Anterior Cingulate Cortex' gyrus ACCg (Somerville et al., 2006; Achterberg et al., 2016). While prior studies tested only adults and adolescents, this study tested for the first time if the same regions are engaged in children, including not only positive and negative social feedback but also a neutral social feedback baseline (see Achterberg et al., 2016), and examined the relations with subsequent aggression.

Table 1
Demographic characteristics of the samples.

	Pilot	Test	Replication
N	19	28	27
% boys	53%	43%	44%
Left handed	none	3	6
AXIS-I disorder	none	none	1 (ADHD)
Mean Age (SD)	8.18 (0.97)	8.23 (0.67)	8.28 (0.65)
Age Range	7.20–10.99	7.03–8.97	7.03–8.97
Mean IQ (SD)	102.76 (11.54)	101.57 (12.33)	104.54 (10.58)
IQ range	85.00–127.50	77.50–125.00	85.00–132.50

2. Materials and methods

2.1. Participants

Participants in this study were part of the larger, longitudinal twin study of the Leiden Consortium on Individual Development (L-CID). Families with a twin born between 2006 and 2009, living within two hours travel time from Leiden, were recruited through the Dutch municipal registry and received an invitation to participate by post. Parents could show their interest in participation using a reply card. For the larger L-CID study, only same-sex twins were included. Opposite-sex twins were included only in the pilot study. The pilot sample consisted of 20 children between the ages of 7 and 10 (11 boys, $M = 8.16$ years, $SD = 0.95$), including 9 opposite-sex twin pairs. Two additional participants were recruited from a participant data base at Leiden University. Two months after the pilot sample, the test and replication samples were recruited. The test and replication sample consisted of 30 same-sex twin pairs (16 boys, $M = 8.22$ years, $SD = 0.67$), including 7 monozygotic pairs. After data collection, but prior to data analyses, first and second born children (within the twin pair) were randomly assigned to the test and replication sample. For a schematic overview of sample selection see Fig. S1 (Supplementary materials). The Dutch Central Committee on Human Research (CCMO) approved the study and its procedures. Written informed consent was obtained from both parents. All participants were fluent in Dutch, had normal or corrected-to-normal vision, and were screened for MRI contra indications. All anatomical MRI scans were reviewed and cleared by a radiologist from the radiology department of the Leiden University Medical Center (LUMC). No anomalous findings were reported.

Six participants were excluded due to excessive head motion, which was defined as >1 mm movement in >20% of the volumes (one from the pilot sample, two from the test sample and three from the replication sample). The final pilot sample consisted of 19 participants, including 8 twin pairs (10 boys, $M = 8.18$ years, $SD = 0.97$), the final test sample consisted of 28 participants (12 boys, $M = 8.23$ years, $SD = 0.67$) and the final replication sample consisted of 27 participants (12 boys, $M = 8.28$ years, $SD = 0.65$). Demographics of the final samples are listed in Table 1. Participants' intelligence (IQ) was estimated with the subsets 'similarities' and 'block design' of the Wechsler Intelligence Scale for Children, third edition (WISC-III; Wechsler, 1997). For all three samples, estimated IQs were in the normal to high range (see Table 1). In all three samples, IQ scores were unrelated to behavioral outcomes of the SNAT (noise blast duration after positive, neutral, negative feedback, all p's > 0.214).

2.2. Social network aggression task

The Social Network Aggression Task (SNAT) as described in Achterberg et al. (2016) was used to measure (imagined) aggression after social evaluation. The task was programmed in Eprime (version 2.0.10.356). Prior to the fMRI session, the children filled in a personal profile at home, which was handed in at least one week